pH RECORDING ELECTROMETER

Model EU-301B

(EU-20-31)

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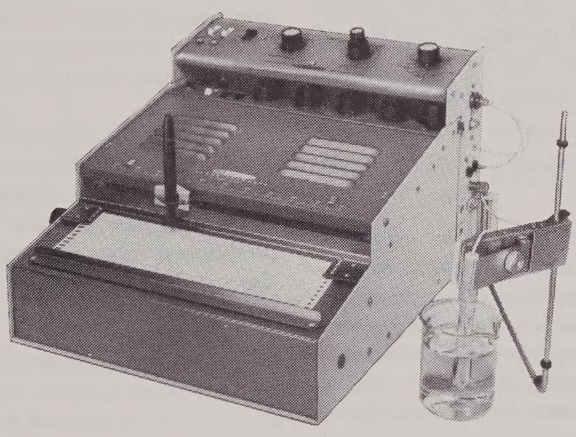
OPERATION OF THE HEATH

pH RECORDING ELECTROMETER



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INTRODUCTION

pH ADAPTER MODULE

The Heath Model EU-20-31 is an all solid-state pH Adapter Module, with a chopper and FET input and zener reference supplies. The Module converts the EUW-20A or EU-20B Chart Recorder into an EU-301B pH Recording Electrometer. This pH Adapter Module also converts the EUW-20M or EU-20V Multi-Speed Chart Recorder into an EU-301V pH Recording Electrometer. The Adapter Module is available separately from the Servo Recorder. It takes only a couple of minutes to connect the pH Module to the Recorder to form a neat compact instrument. This Manual covers the connection of the pH Module to the Servo Recorder and full operating instructions for the Recording Electrometer.

pH RECORDING ELECTROMETER

The Heath pH Recording Electrometer can be used as a convenient and easy-to-operate general-purpose laboratory pH meter or as a research instrument to provide exacting pH and millivolt measurements. The recording feature makes it unnecessary to stop, read, and write down the pH values for successive samples. It is only necessary to mark the sample number next to the recorded pH value on the chart. On all scales and at all times the Electrometer operates as a true null-point instrument with a stable zero point, yet it is direct reading on all scales. The recording feature enables the pH or millivolt values from very high or low impedance transducers to be recorded continuously on a 10-inch chart so complete acid-base titration curves, reaction-rate curves, oxidation-reduction titration curves, and stability curves can be readily obtained.

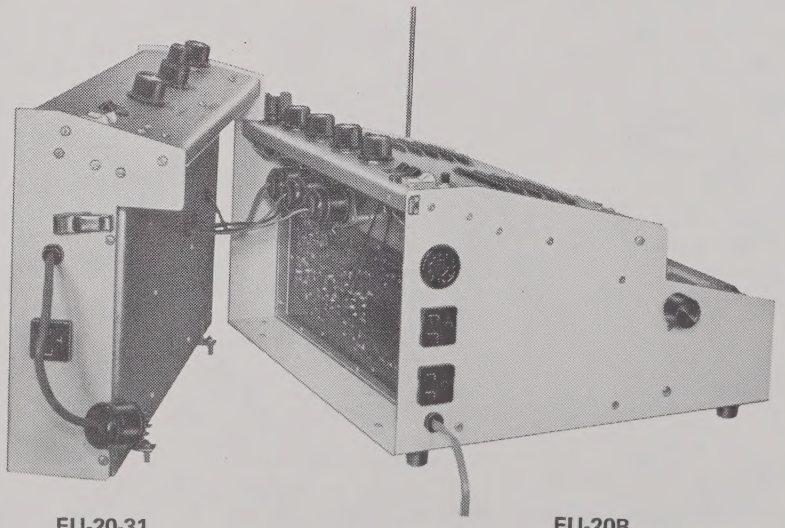
The expanded scales make it possible to measure the pH very precisely and accurately. Therefore, reliable measurements can be made for the determination of K_w, activity coefficients, formation constants, and junction potentials.

In addition to the five full-scale pH spans, there are five calibrated millivolt spans that provide direct recorded millivolt readout from high or low impedance potential sources. The Electrometer can be used for redox, precipitation and complexation titrations, nonaqueous titrations, the determination of sodium and potassium and other ions with the new specific ion electrodes, and all potentiometric measurements.

The circuitry is connected for simple modifications by plug-in adapters. One plug-in adapter was described in the May, 1964 issue of Journal of Chemical Education. This adapter converts the pH Recording Electrometer into a precision recording photometer for spectrophotometry, and also as an ionization detector readout for gas chromatography.

The many outstanding features that are packed into this one, extremely sensitive, accurate, and compact Recording Electrometer are apparent from the specifications.

The Heath pH Recording Electrometer is based on a design by Professor H. V. Malmstadt of the University of Illinois, described in the March, 1964 issue of the Journal of Chemical Education. Portions of the description sections in this Manual have been taken from this paper by permission of the author and copyright owner, the Division of Chemical Education ACS.



EU-20-31 EU-20B

PRINCIPLES OF OPERATION

EXPLANATION OF OPERATION

Scientific measurements of high precision and accuracy are almost always performed by comparison methods, often referred to as null-point procedures. As illustrated in Figure 1, an unknown DC voltage E_u is determined by comparing it with a reference DC voltage E_s that can be continuously varied (as indicated by the arrow through the symbol for the voltage source) until it is equal to E_u. In practice, then, the reference voltage is varied until a detector indicates that there is no difference between the E_s and E_u.

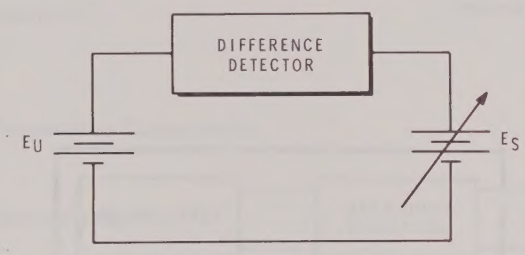


Figure 1 Block diagram of a null detector

The classical difference for voltage measurements is the galvanometer, but the modern detector is usually some type of chopper-amplifier combination. If the detector indicates no difference, then $E_u = E_s \pm e$, where E_s is the stated value for the reference source at the null point, and e is an error dependent on the sensitivity of the detector and the accuracy of the reference standard. It is important to recall that the absolute characteristics of the difference detector are not important if it is sufficiently sensitive under the measurement conditions. In other words, if the detector undergoes a 20% change in sensitivity from 1.0 μV/div on one day to 1.2 μV/div on the next, the change would cause less than a 0.1% error in determining E_u values in the millivolt range. Therefore, given a sufficiently sensitive detector, the accuracy of measuring E_u is primarily dependent on the accuracy of the reference source.

Another important feature of the comparison method for DC voltage measurements is that at the null point there is no measurable current flow. Therefore, the electrodes of an unknown cell are not polarized and there is no voltage drop across the cell's internal resistance, two facts which lead to greater accuracy by the null procedure and the possibility of measuring the emf (electromotive force) of a cell.

Because of the high accuracy it would seem reasonable to use a true null-point method for the electrometric determination of pH, wherein the emf of a suitable electrochemical cell is directly related to pH. Indeed, several of the best commercial pH instruments utilize the direct comparison method. Unfortunately, the usual pH comparison instrument requires that the reference source be manually adjusted until a null point is reached, and then the value of E_s is read from a dial. It is obviously more convenient and rapid to read the pH directly without the manual adjustment of a reference. Also, in some cases it is necessary to record pH changes continuously. Consequently several so-called direct-reading pH meters that utilize various electronic feedback schemes and a panel meter have been developed. The meters are generally accurate to about 1% of full-scale. Therefore, if the full-scale meter span is 7 pH units, the accuracy is about 0.07 pH unit.

It is possible however, to have both a true null-point comparison method and the direct-reading advantage by using automatic self-balancing of the reference voltage. This is illustrated in Figure 2. In this case E_U represents the unknown emf of a glass-calomel cell which is directly related to pH values. A vibrating contact alternately looks at E_U and the E_S. If there is any difference between them, an AC voltage is developed at the frequency of the vibrating contact and of an amplitude proportional to the difference (E_U - E_S). The AC voltage is amplified and used to operate a phase-sensitive servo motor which is mechanically coupled to the variable reference source. If E_U is larger than E_S, the motor turns to increase E_S; if E_S is larger than E_U, the motor reverses direction so as to decrease E_S. By proper design of the servo system, a null point can be automatically attained in less than one second. By attaching a pointer and scale to the reference source, the voltage pH value can be read directly from the scale. Also, the position of a writing pen that is mechanically coupled to the reference source will indicate pH as a function of time on a chart paper that is moved under the pen at a constant rate.

The direct comparison of unknown and reference and the automatic variation of the reference to a null point provide the combination of high accuracy, direct-reading convenience, and the recording of pH values, all of which are desirable for most pH applications. These features are inherent in the design of the EU-301B pH Recording Electrometer.

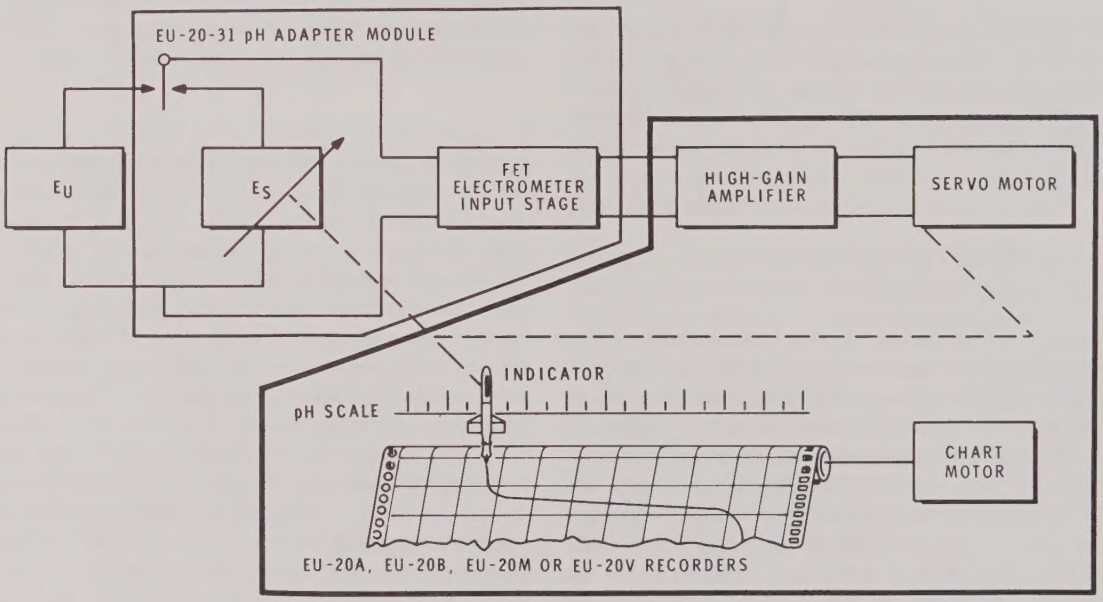


Figure 2 Block diagram of a null-point comparator with direct read-out

SPECIFICATIONS

pH Ranges	Full-scale pH spans of 1, 2, 5, 10, and 14. Any 1 pH unit, 2 pH units (etc.) over entire pH region of interest can be switched for full-scale presentation on 10" scale or recorder chart.
MV Ranges	Full-scale millivolt spans of ±100, 200, 500, 1000, and 1400. There are fourteen calibrated 100 MV increments of zero suppression that can be switched in on all millivolt spans.

Direct-Reading	pH is read directly from a 10" scale; expanded ranges are made direct-reading by interchangeable scales (6.000 - 8.000 pH, etc.).
Recording	Chart with 10" grid on 120 foot roll moves at selected rates with the EU-20V. The EU-20B moves the chart at a standard rate of 2"/min. Special motors for chart speeds as slow as 2"/hr. and as fast as 12"/min. are available from the Heath Company. See the EUW-20A, EU-20B, EUW-20M, or EU-20V Manual.
Scale Readability	0.1% of full-scale span. (0.001 pH on span of 1 pH, 0.01 pH on span of 10 pH, 0.05 MV on span of 100 MV, etc.)
Accuracy	Better than 1% of any calibrated full-scale span, 0.005 pH on span of 1.
Temperature Compensation	Calibrated 0 to 100 degree C manual control. Automatic control by accessory Thermistor probe.
Source Resistance	0 to more than 2000 megohms.
Electrode Receptacles	Accepts glass and reference electrodes from major manufacturers without adapters (Beckman, Corning, Coleman, Leeds And Northup, Fischer, Sargent, etc.).
Electrode Holder	Accommodates electrodes of different diameters, from pencil-size combination electrodes to the largest-sized glass and calomel electrodes.
Adapters	Adapters can be constructed for current measurements, current and voltage integration, etc., and are easily plugged in because of the modular design and connector arrangement.
Modular Construction	The Model EU-301B consists of a standard Heath EU-20B Servo Recorder and Heath plug-in pH Module EU-20-31 connected to form one compact instrument. The EU-301M is the same as the EU-301B except that it has the multispeed chart drive EU-20V recorder.
Power Requirements	120/240 volts, 60 Hz: 45 watts; 50 Hz: 50 watts. (A different gear is needed for proper speed of chart paper for 50 Hz operation.)
EU-301B Dimensions	10-1/2" high x 14-1/2" wide x 16" deep.
EU-20-31 Net Weight	6-1/2 lbs.
EU-301B Net Weight	22 lbs.

INSTALLATION

The pH Adapter Module becomes an integral part of your Chart Recorder when properly installed. Quick interchange of modules for different applications is made possible by the use of plug-in connectors and simple mounting of the Module to the Recorder.

Two guide pins in the bottom of the Module fit into matching holes in the bottom of the Chart Recorder, as shown in Figure 3. The Module is then securely fastened in place by means of the suitcase type latches that are supplied. The Model EU-20B Chart Recorder has holes for attaching the latch hooks. The Model EUW-20A requires that the holes be drilled if you desire to use the latches for mounting the Module.

If your Chart Recorder has its rear panel installed, or if another type of module is attached, remove it from the Recorder. Then remove sockets A, B, and C. The first three steps that follow are for attaching the latch hooks to your Chart Recorder.

( ) If your Chart Recorder does not have holes provided for the latch hooks, cut out the two templates from Figure 3. Use these templates and a center punch to mark the hole centers in each side of the Recorder.

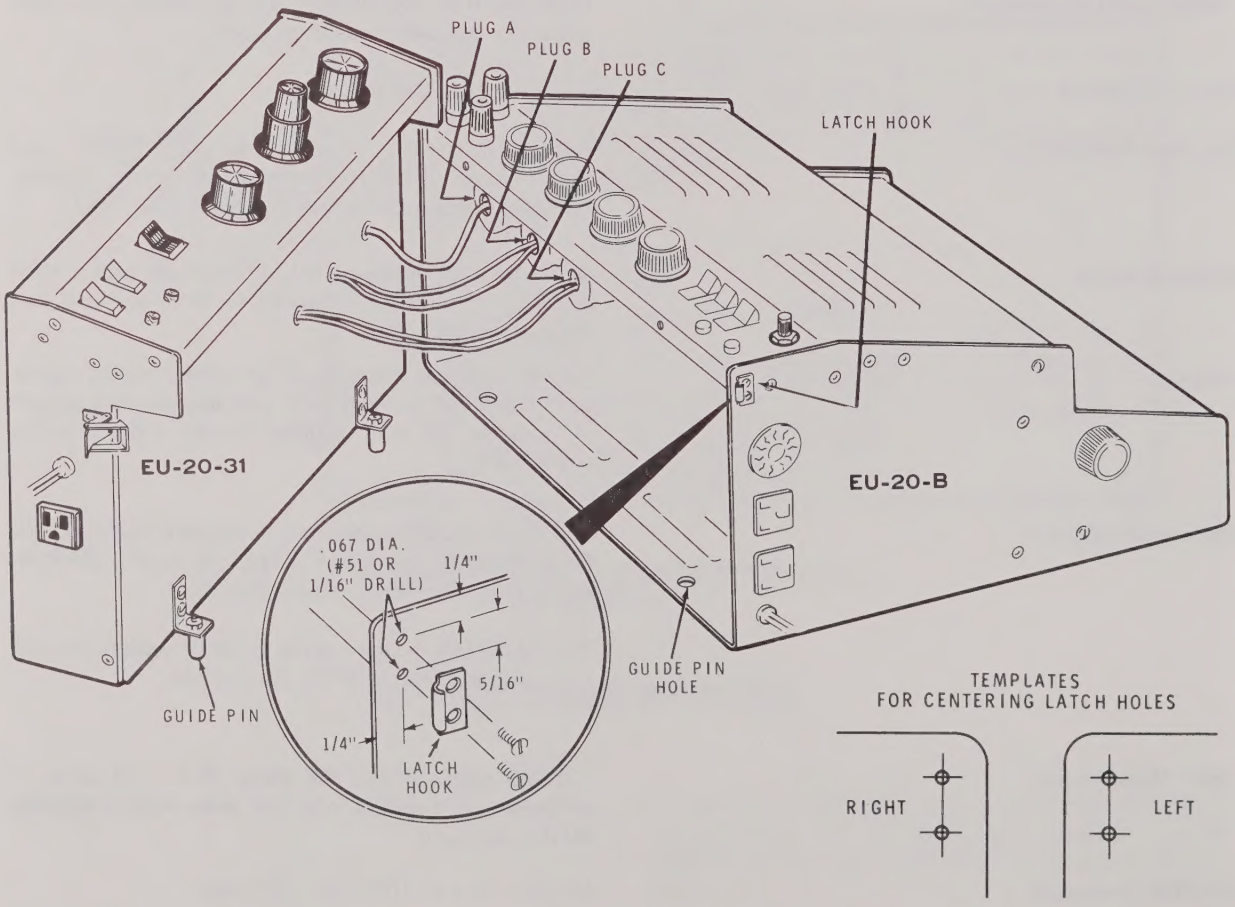


Figure 3 Latch hook installation

( ) Drill two 1/16" diameter holes (#51 numbered drill size) through each side of the Recorder at the center-punched locations.

( ) Locate the two latch hooks and four screws that are supplied with the Module. Mount one latch hook with two screws on each side of the Recorder as shown in the inset drawing of Figure 3.

( ) Position the pH Adapter Module at the rear of the Chart Recorder as shown in Figure 3.

( ) Connect the three sockets from the Module to corresponding plugs A, B, and C on the rear of the Recorder.

( ) Refer to Figure 4 and fit the two guide pins on the bottom of the Module into the guide pin holes in the bottom of the Recorder.

( ) If you have latch hooks installed on your Chart Recorder, latch the Module to the Recorder as shown in the inset drawing on Figure 4.

( ) Connect the 11-pin plug from the Module to the 11-pin accessory socket on the Recorder.

( ) Replace the back panel on the Module.

NOTE: The chopper must be removed from the Servo Recorder while the pH Module is being used. If your Recorder is the Model EUW-20A, the mercury reference cell should also be removed.

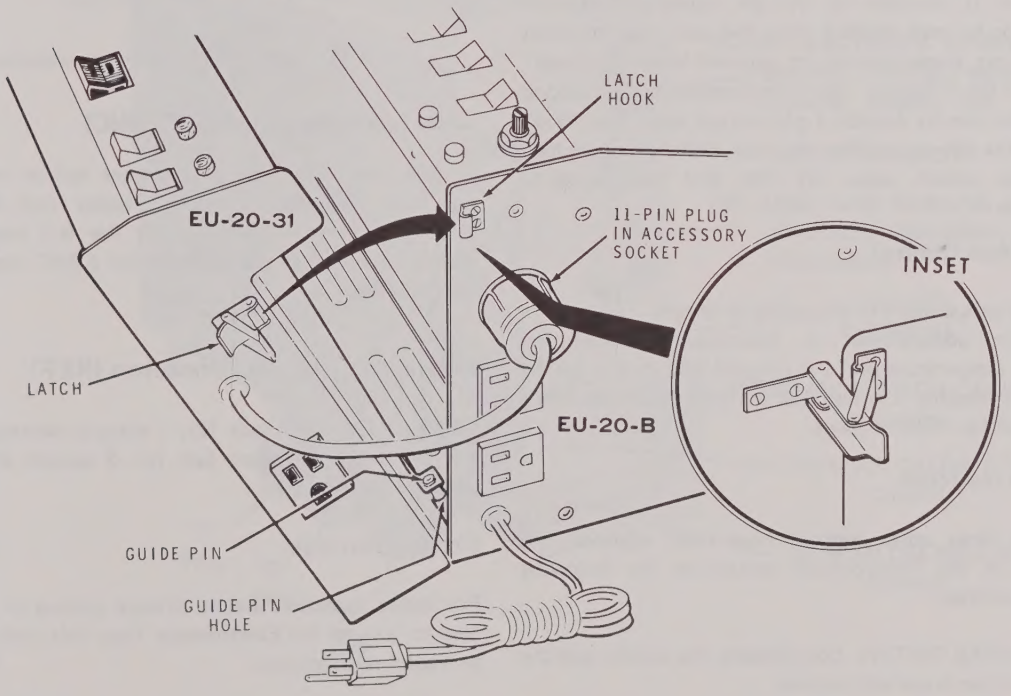


Figure 4 Installing pH Module

OPERATION

CONTROLS AND ELECTRODE CONNECTIONS

Before using the pH Recording Electrometer, read the following information to familiarize yourself with the operation of the controls. These controls and electrode connections are located on the Module section. Refer to Figure 5 (fold-out from Page 9).

Span Switch

Select any of the five pH full-scale spans or any of the five millivolt full-scale spans.

Fine and Coarse Standardization Controls

For pH measurements, these controls are adjusted to indicate on the scale, the exact value of a standard buffer. This makes it possible for the pH values of unknown solutions to be read directly from the scale. For millivolt measurements, these controls are adjusted to set the "zero" position of the indicator. The coarse control can be used to suppress the pen by exactly 1 pH unit per step (total 14 pH units) on the pH spans. When the span switch is set for MV, the coarse switch steps off 100 MV increments of suppression.

Temperature Control

Set to the temperature of the buffer or sample. This manual temperature compensator is disconnected when the automatic temperature probe is plugged into plug W on the rear of the Module. It is also disconnected when the SPAN switch is set for millivolt spans.

Function Switches

After the three other controls have been adjusted, the operation of the Electrometer centers on the following function switches.

PEN REVERSE SWITCH: Complement the switch, and the direction of pen travel will reverse.

CHART: In the ON position, the Recorder chart is in motion for a continuous indication on the chart.

SERVO: In the ON position, the pen will continuously move to the null position to provide direct readout of pH or MV values.

AC Accessory Socket

Provides 120 volts AC when the Recorder Power switch is in the ON position.

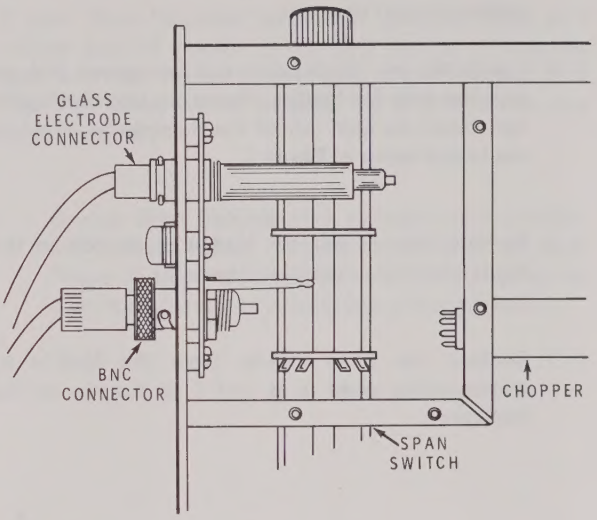


Figure 5A Identification of connectors

Glass Electrode Inputs (B-C, BNC)

A glass electrode with a connector similar to those on Beckman, Corning, Coleman, Fischer and most other Electrodes (Figure 5A) fits into the B-C input. A glass electrode, or other transducer with a BNC connector fits into the BNC input.

Reference Electrode Connectors (REF)

Reference Electrode jack No. 1 accepts banana type plugs and Reference Electrode jack No. 2 accepts the pin type plugs.

Ground Terminal

For stable operation and to prevent pickup of noise, it is best to ground the Electrometer from this terminal (GND) to a good earth ground.

Standardization Calibrate Control

This control (STD CAL) is used to calibrate the COARSE STANDARDIZATION switch to index 1 pH per step.

MV Calibrate Control

This control (MV SPAN CAL) is used for calibration of nominal full-scale MV spans to the exact MV spans by use of a standard MV source.

pH Calibrate Control

The pH CALIBRATE control (pH SPAN CAL) is adjusted until an input of 1 pH moves the pen 1 pH on the graph. NOTE: This calibration should be rechecked after changing spans.

CHART RECORDER CONTROLS

Power Switch

If you are using the EU-20B Recorder, only the POWER switch should be in the ON position. If you are using the EUW-20A Recorder, the POWER switch should be in the STANDBY position. This will provide power and proper switching to the 11-pin accessory socket on the Recorder.

Damping Control

The DAMPING control provides critical damping for the recording pen. For proper adjustment of the DAMPING control, refer to your Recorder Manual.

Hum Adjust Control

The HUM ADJUST, or 60~ NULL control is used to balance out 50/60 cycle noise to provide maximum sensitivity. The adjustment procedure can be found in the Recorder Manual. This adjustment should be made with the Module installed on the Recorder, the electrometer connected, and the unit operating.

ELECTRODE AND SCALE SETUP

Electrode Support Rod Removal

Refer to Figure 6 for the following step.

NOTE: The electrode rod can be removed from the pH Module when the Module is to be used for other applications not requiring an electrode support.

( ) Loosen and remove the two screws holding the rod support bracket. See the inset drawing.

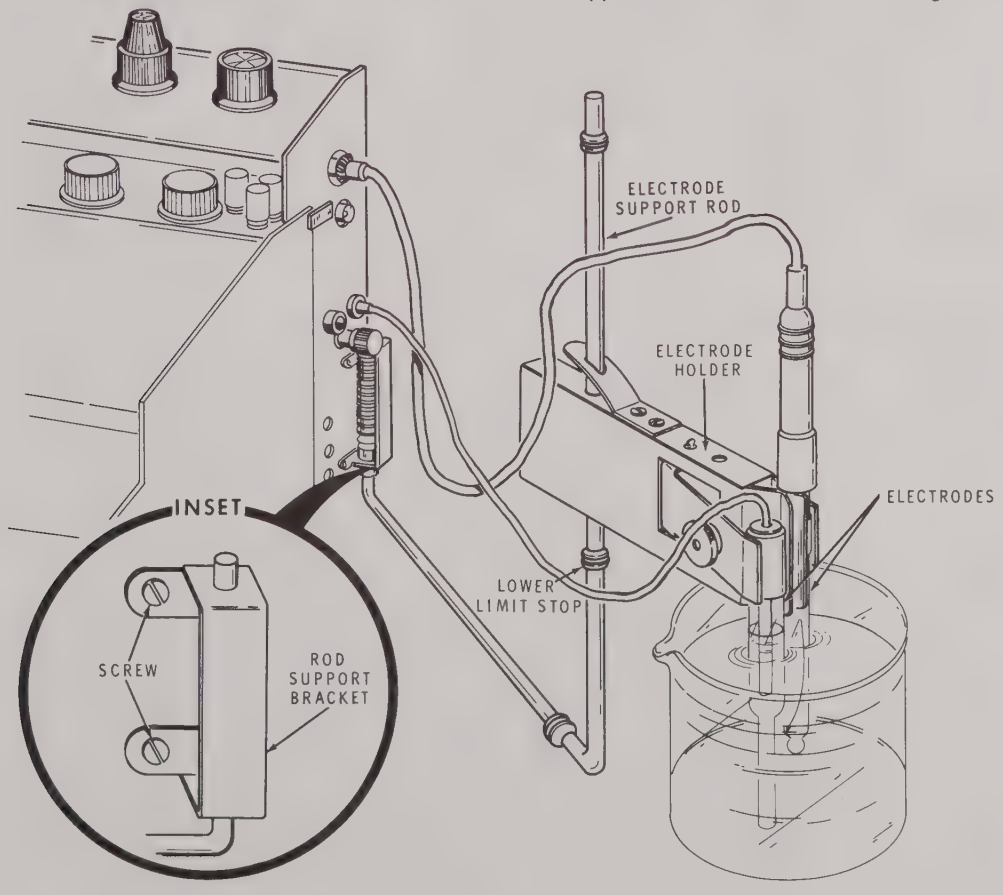


Figure 6 Electrode holder and connections

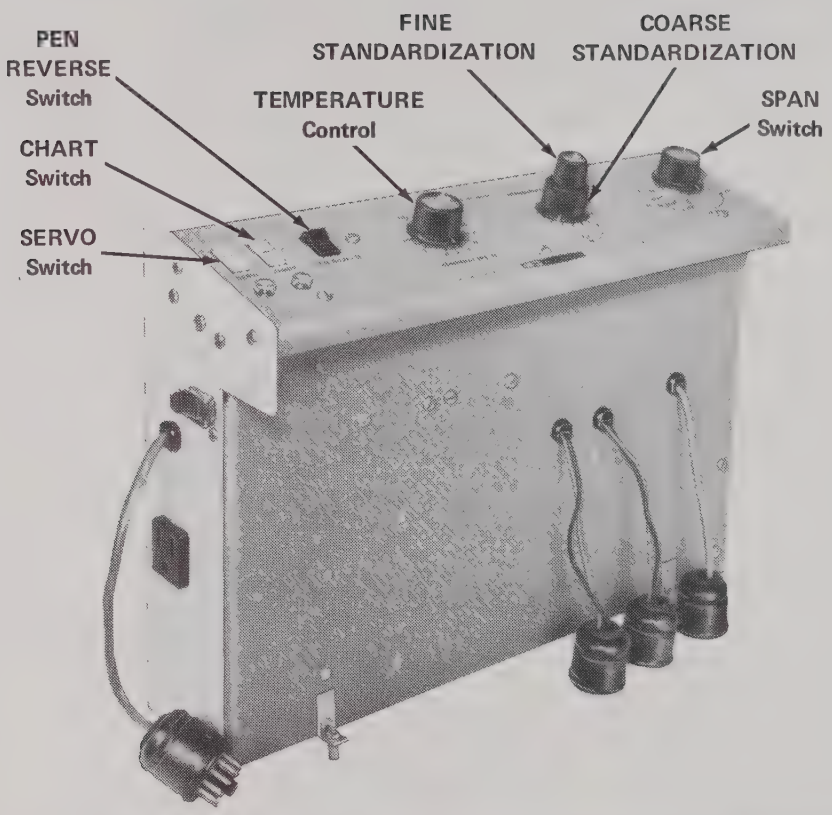

PEN
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CHART
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FINE
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STANDARDIZATION
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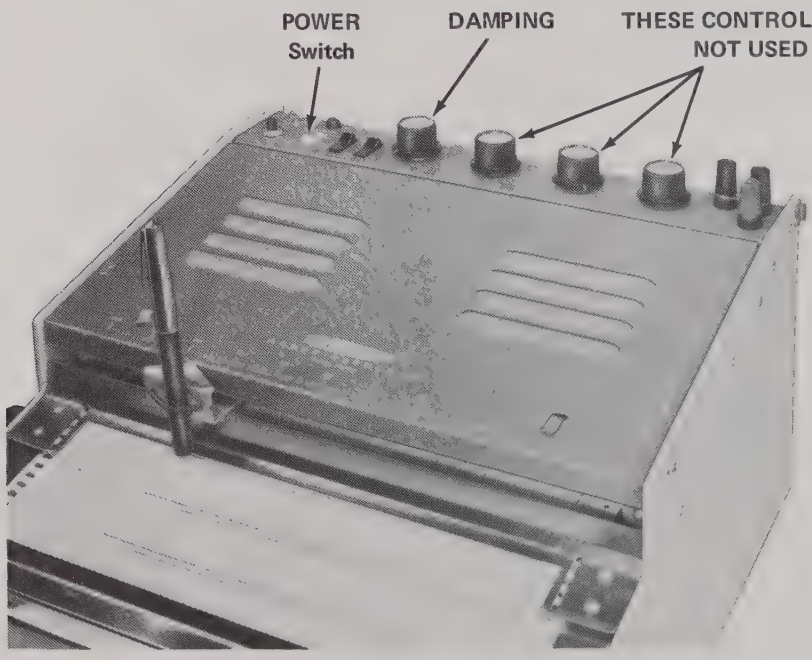
Switch


POWER
Switch
DAMPING
THESE CONTROLS ARE
NOT USED

F

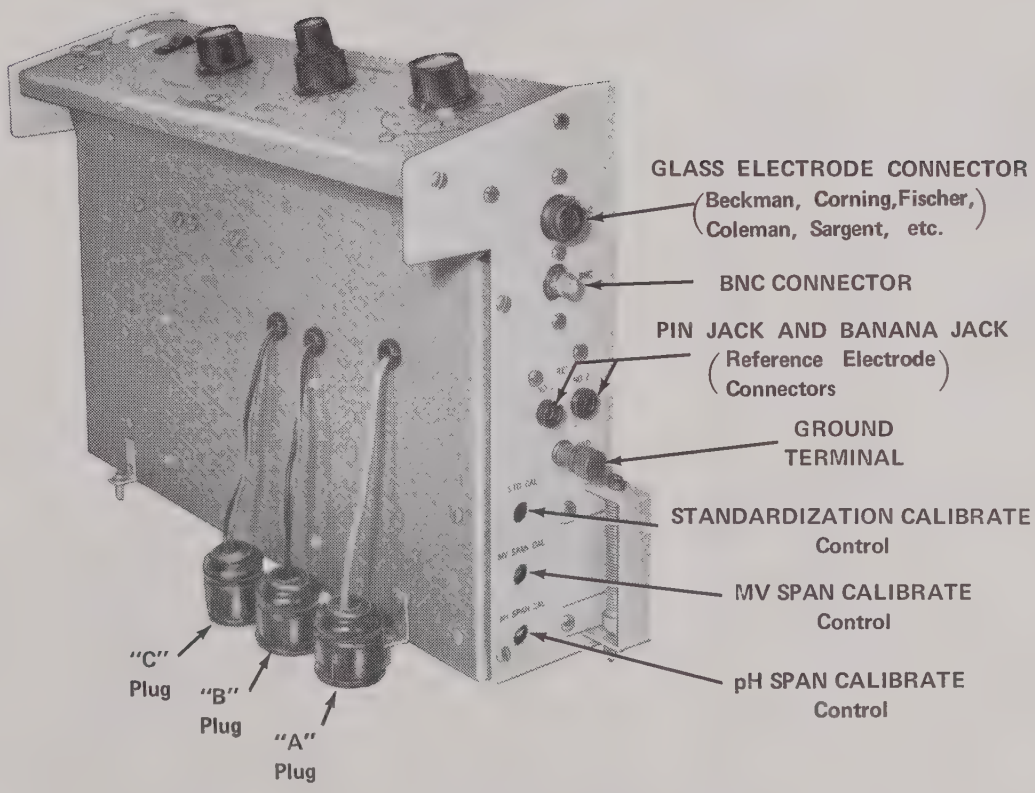

GLASS ELECTRODE CONNECTOR
(Beckman, Corning,Fischer,
Coleman, Sargent, etc.)
BNC CONNECTOR
PIN JACK AND BANANA JACK
(Reference Electrode
Connectors)
GROUND
TERMINAL
STANDARDIZATION CALIBRATE
Control
MV SPAN CALIBRATE
Control
pH SPAN CALIBRATE
Control
"C"
Plug
"B"
Plug
"A"
Plug

FIGURE 5

Electrode Holder

The electrode holder is movable on the electrode support rod. Two of the rubber grommets on the electrode support rod are limit stops for the electrode holder. The electrode holder height is adjusted by sliding the holder on the support rod.

INTERCHANGEABLE SCALES

Several different scales are provided so that direct readings can be obtained for various pH or MV spans. These scales slide under the clips as shown in Figure 7. Choose the scale that will give you a direct reading of pH or MV. One blank scale is provided so that it can be marked as desired.

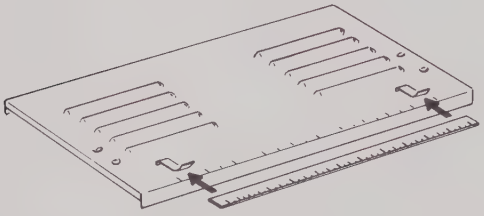


Figure 7 Installation of interchangeable scales

pH ELECTRODE MAINTENANCE

It is common practice to leave the glass and calomel electrodes soaking in water when they are not in use. Electrodes which have been left to dry out in air must usually be soaked in water for several hours to become stable.

Check the calomel electrode often and keep it filled with saturated KC1 solution. If the calomel electrode has a fiber junction at the tip, it can become plugged when used in solutions with suspended matter. The plugged fiber can usually be opened by boiling the tip of the electrode in diluted nitric acid.

Glass electrodes that are used in solutions with suspended matter may drift, especially when used in biological samples containing protein. Any accumulated coating should be removed by cleaning gently with a detergent and water.

CONSIDERATIONS FOR HIGH PRECISION AND ACCURACY

Buffer solutions in opened bottles change with time. Therefore, fresh buffer solutions should be used for the most accurate work. Do not pour used buffer back into the reagent bottle. Keep the bottle capped to prevent evaporation and contamination.

The electrodes should be rinsed with distilled water and gently blotted dry with tissue to prevent carryover between samples or buffer.

The pH-sensitive portion of the glass electrode must be completely immersed in the sample or buffer solution, and it is important that the glass electrode does not touch the wall or bottom of the sample container.

Electrodes and samples should be at the same constant temperature because thermal gradients will result in small potential drifts that will be observed on the expanded pH scales.

ELECTRODE STANDARDIZATION

When using a glass-calomel electrode pair, there are many factors other than pH that can affect the input voltage to the Electrometer. There are stirring effects, the variation of liquid junction potential, variation of glass asymmetry potential, glass electrode contamination and scratches, and alkali-effects that should be considered for significant measurements.

Although the zero-point stability of the Electrometer is essentially perfect from day to day, the characteristics of the glass-calomel electrodes change over short periods depending on their use and condition. Therefore, it is important to frequently standardize the electrode system with standard buffers.

Nontheoretical Electrode Behavior

"Electrode Standardization Procedure I" (on the next page) follows the usual standardization procedure employed with most pH meters. However, it assumes that the glass electrode response follows the theoretical values. It is a more accurate procedure to check electrode response for the region of interest with another one or more standard buffers, and then compensate for nontheoretical electrode behavior as instructed in "Electrode Standardization Procedure II." This is sometimes called the "2-point standardization" procedure.

ELECTRODE STANDARDIZATION PROCEDURE

I

Regular Procedure
(Theoretical Electrode Response)

1. Set the Servo Recorder Power Switch to ON (for the EU-20B) or STANDBY (for the EUW-20A). Refer to the Power Switch information on Page 9 if necessary. The EUW-20A Recorder must remain in this standby mode for all pH and MV measurements.

2. Turn the SPAN switch to the desired value. This value will depend on the amount of scale expansion preferred.

3. Immerse the electrodes in a buffer with a pH value in the region of samples to be measured (e. g. buffer pH 7.00 at 25 degrees C).

4. Set the TEMPERATURE control to the temperature of the buffer, or use automatic temperature control (see Page 8).

5. Turn the SERVO and CHART switches on.

6. Turn the DAMPING control all the way counterclockwise. If the pen "jitters", adjust this control just enough to stabilize the pen.

7. Adjust the FINE and COARSE STANDARDIZATION controls so the pen is coincident on the scale with the buffer value.

8. Turn the SERVO and CHART switches off.

NOTE: If you change the setting of the pH SPAN switch, it will be necessary to repeat steps 6 and 7.

II

Two-Point Procedure
(Nontheoretical Electrode Response)

1. Set the Servo Recorder Power Switch to ON (for the EU-20B) or STANDBY (for the EUW-20A). Refer to the Power Switch information on Page 9 if necessary. The EUW-20A Recorder must remain in this standby mode for all pH and MV measurements.

2. Set the COARSE STANDARDIZATION at 6.

3. Set the TEMPERATURE control to the temperature of the buffer.

4. Adjust the FINE STANDARDIZATION control so the pen is exactly at 7 on the scale with the electrodes in an accurate buffer of pH 7.00 ±0.01.

5. Rinse, dry, and immerse the electrodes in another buffer with a pH value near the range of interest (Ex. 4.00).

6. When the indicator reaches a steady value, adjust the pH CALIBRATION control so the pen points to the exact value of the buffer. The time required to reach a steady value depends on the specific electrode response for the specific sample. (Allow at least 1 minute. The instrument lag is only a few seconds with 500 megohms electrode resistance and shorter for lower resistances.)

7. Repeat the above procedure several times for maximum accuracy.

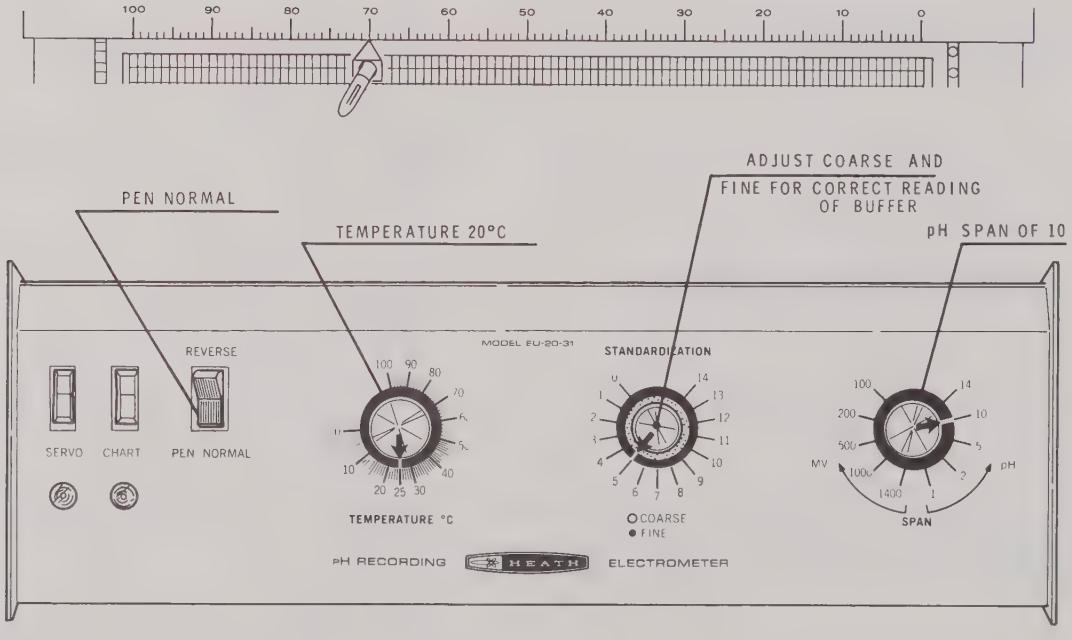
To use the COARSE STANDARDIZATION switch in any position other than 6, it is necessary to calibrate the lower STANDARDIZATION circuit. This is done by adjusting the STANDARDIZATION calibrate control so the pen moves 1 pH unit for each step of the COARSE STANDARDIZATION switch.

pH MEASUREMENT OF SAMPLE

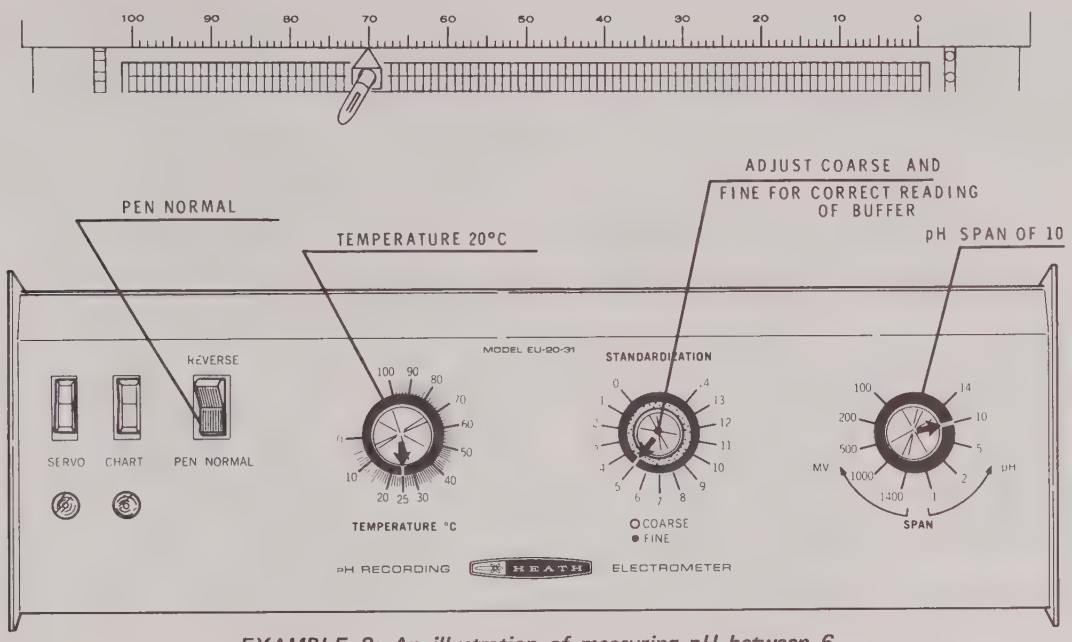
1. Remove the buffer solution, rinse the electrodes with distilled water and gently blot dry with soft tissue.
2. Immerse the electrodes in the sample solution.
3. Set the TEMPERATURE control to the temperature of the sample.
4. Turn on the SERVO switch, and read the pH value when the pen remains at a steady value. Also turn on the CHART switch if the pH values are to be recorded.
5. Turn the SERVO and CHART switches off.
6. Remove the sample, rinse the electrodes with distilled water and blot them dry. Store the electrodes as recommended by the manufacturer.

pH MEASUREMENT EXAMPLES

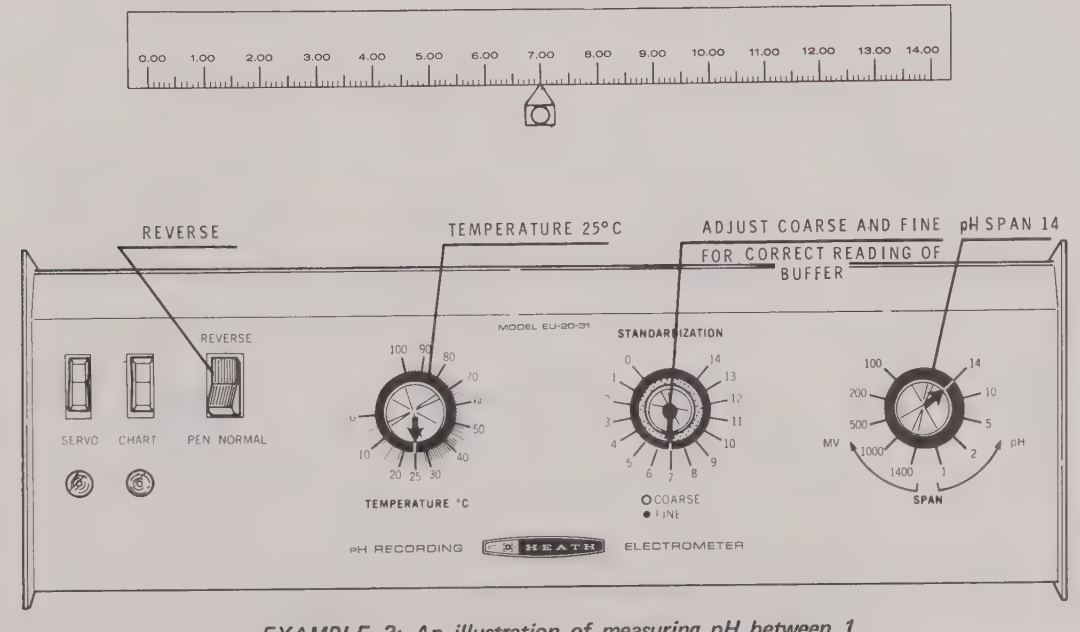
NOTE: These examples assume the unit has been calibrated. The standardization settings are approximate and may vary depending upon the electrodes used.



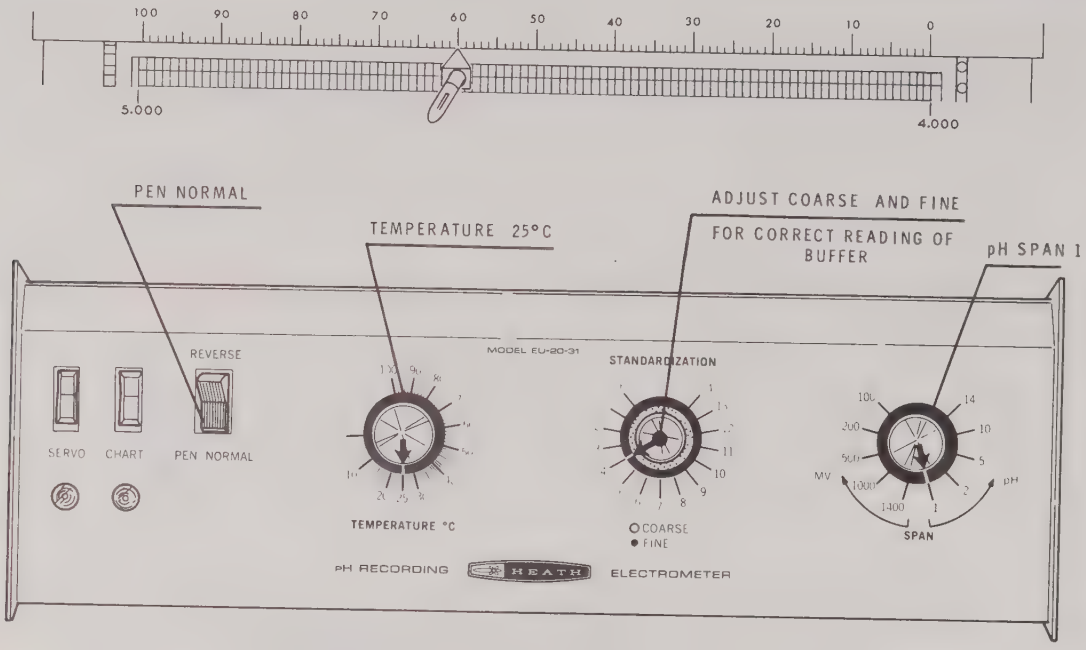
EXAMPLE 1: An illustration of measuring pH between 0 and 10 with the temperature of the sample at 20 degrees C. The scale readings are from right to left.



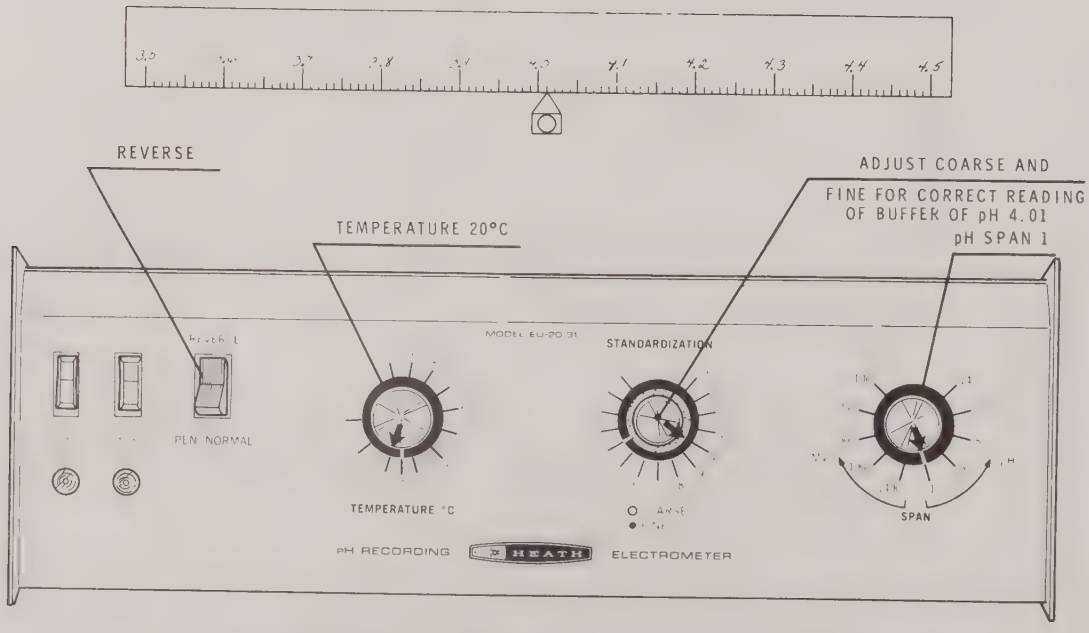
EXAMPLE 2: An illustration of measuring pH between 6 and 8 with the temperature of the sample at 37 degrees C. The scale and recording are read left to right.



EXAMPLE 3: An illustration of measuring pH between 1 and 12 during a titration with the temperature of the solution at 25 degrees C. The scale and recording are read left to right.



EXAMPLE 4: An illustration of measuring pH between 4 and 5 with the temperature of the sample at 25 degrees C. The scale and the recording are read right to left.



EXAMPLE 5: An illustration of measuring pH between 3.5 and 4.5 with the temperature of the sample at 20 degrees C. The scale and recording are read left to right.

MILLIVOLT MEASUREMENTS

A shielded cable with a BNC-type connector has been furnished with the Electrometer for making millivolt measurements. Additional millivolt cables can be made by using the shielded cable and connectors from damaged electrodes.

1. Set the Recorder in the STANDBY mode.

2. Turn the SPAN switch to the desired millivolt span.

3. Check the PEN TRAVEL switch for the desired Left To Right or Right To Left operation, and correct polarity, for increasing MV values. See Millivolt Measurement Examples which follow for further information on steps 4, 5, and 6.

4. Set the COARSE STANDARDIZATION switch as designated by the PEN TRAVEL position (either start at "0" or at "14"), depending on MV input polarity.

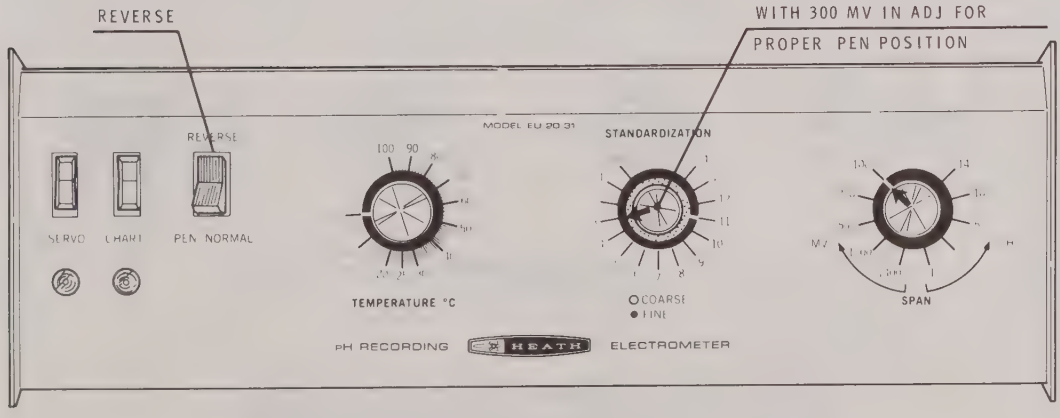
5. With zero volts applied to the input (but not an open circuit), turn on the SERVO and CHART switches, and adjust the STANDARDIZATION control so the pen is at the desired zero. For full-scale spans Right To Left, adjust the control so the zero is at the right end of the scale, etc.

NOTE: When the instrument is in the MV function, the TEMPERATURE control has no effect.

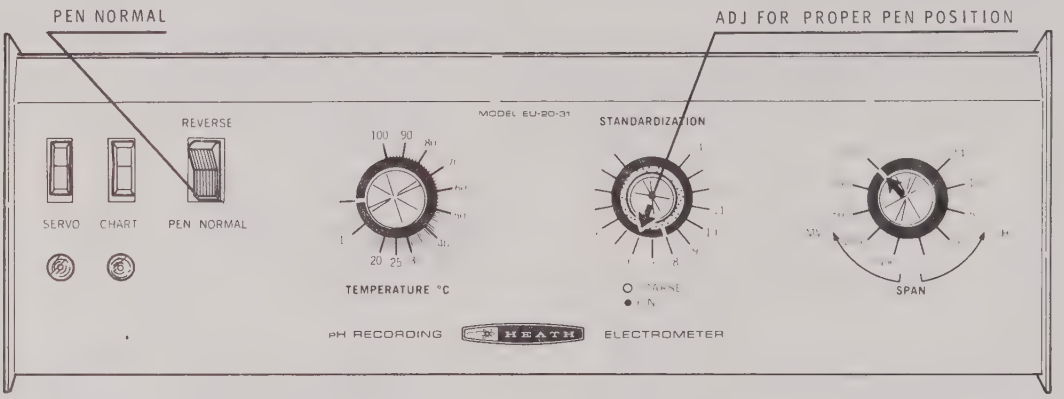
6. If the input signal drives the pen to more than full-scale, either shift to the next larger span, or introduce calibrated 100 MV-per-step suppression with the COARSE STANDARDIZATION switch to bring the pen on scale. If suppression is used, the final millivolt reading is the sum of the number of suppression steps times 100, plus the scale reading.

7. Turn off the SERVO and CHART switches.

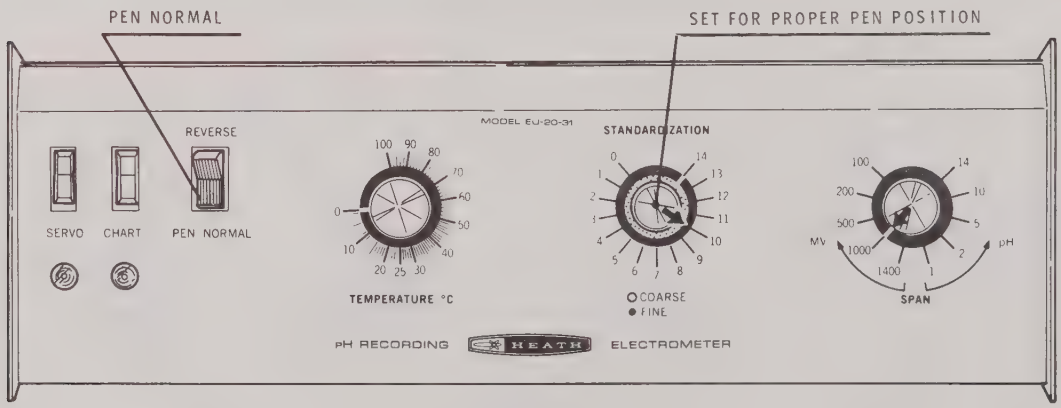
MILLIVOLT MEASUREMENT EXAMPLES



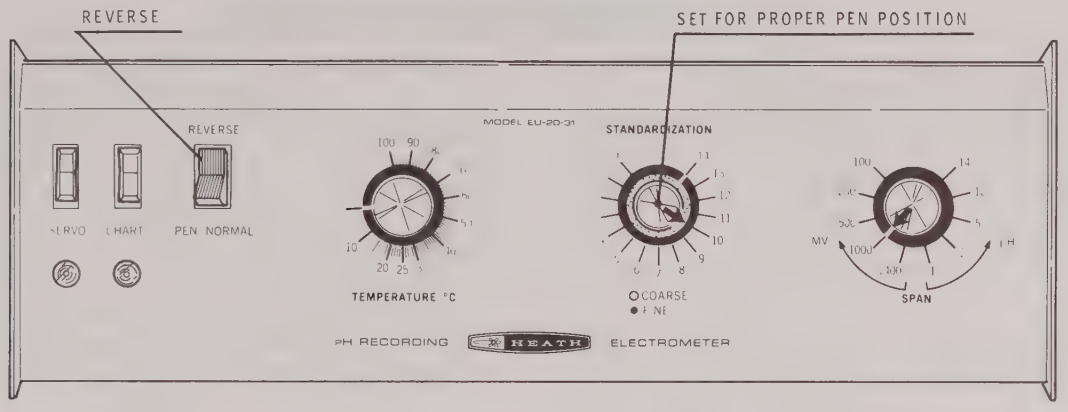
EXAMPLE 1: An illustration of measuring between +300 and +400 millivolts with the pen moving full-scale. +300 millivolts will be on the right edge and +400 millivolts will be on the left edge of the chart paper. Set all controls and switches as shown.



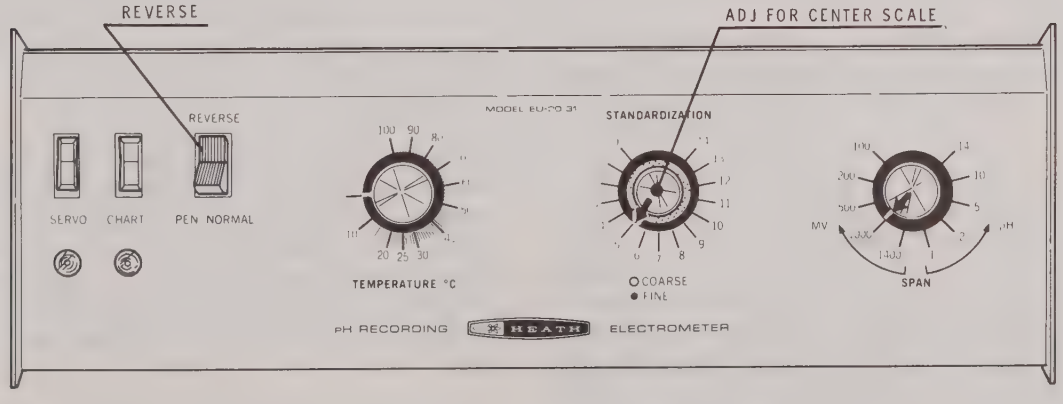
EXAMPLE 2: An illustration of measuring millivolts between -600 millivolts and -700 millivolts with the pen moving full-scale. -600 millivolts will be on the right edge and -700 millivolts will be on the left edge of the chart paper. Set all controls and switches as shown.



EXAMPLE 3: An illustration of measuring millivolts between 0 and -1000 millivolts full-scale with 0 on the right edge and -1000 millivolts on the left edge of the chart paper. Set all controls and switches as shown.



EXAMPLE 4: An illustration of measuring millivolts between 0 and 1000 millivolts full-scale with 0 on the right edge and 1000 millivolts on the left edge of the chart paper. Set all controls and switches as shown.



EXAMPLE 5: An illustration of measuring millivolts between -500 millivolts and +500 millivolts full-scale with 0 at the center of the chart paper, and -500 millivolts on the right edge. Set all controls and switches as shown.

INSTRUMENT CALIBRATION

TABLE 1*
THEORETICAL MILLIVOLTS PER pH UNIT

Temperature °C	MV/pH
0	54.2
5	55.2
10	56.2
15	57.2
20	58.2
25	59.2
30	60.2
35	61.1
40	62.1
45	63.1
50	64.1
55	65.1
60	66.1
65	67.1
70	68.1
75	69.1
80	70.1
85	71.1
90	72.1
95	73.0
100	74.0

*NOTE: For more complete tables see "Electrometric pH Determinations, Theory and Practice", by R. G. Bates, J. Wiley and Sons, Inc., N.Y.

When your Heath pH Recording Electrometer was calibrated at the factory, it was assumed that the pH electrodes would provide the theoretical millivolt response per pH unit shown above in Table 1. Therefore, since many commercial electrodes do not have this perfect theoretical response, especially over a wide pH range, it may be necessary to recalibrate the pH spans for the specific electrodes being used. This can be accomplished by using two reliable standard buffers that cover the pH range of interest.

Connect any reliable standard millivolt source, such as a potentiometer, to the input jacks of the pH Module. The Heath Model EUA-20-12 pH Test Unit is especially useful because it provides fourteen steps calibrated in pH units from 0 to 14 for several temperatures (10, 25, 50, and 90 degrees C). Therefore, temperature dials can be checked and, of course, pH spans can be calibrated for theoretical values. Another control enables the output source impedance to be varied from 100 kilohms to 1000 megohms so that the performance of pH meters can be readily checked.

Begin the calibration by following the instructions for "Nontheoretical Electrode Behavior" on Page 10. Then, after these steps are completed, proceed to the "Standardization Calibration" instructions.

STANDARDIZATION CALIBRATION

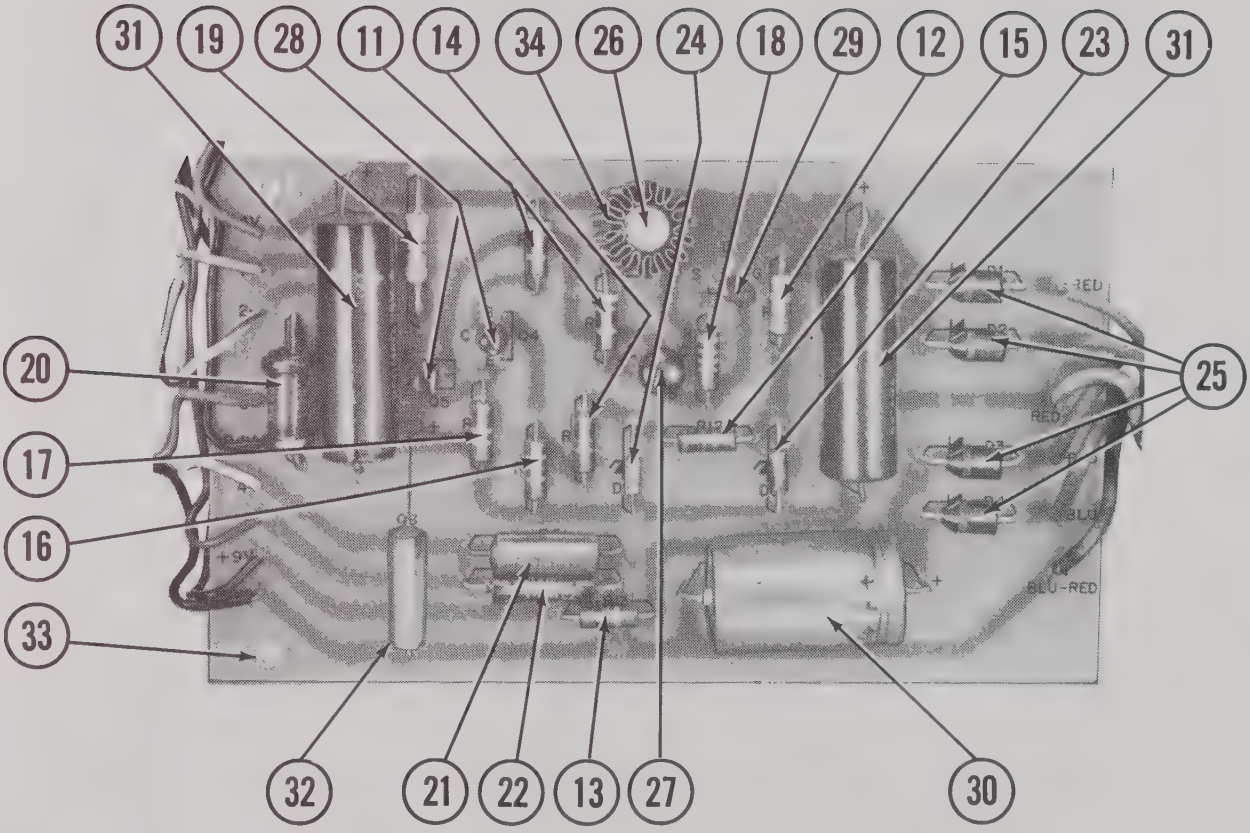
Turn the COARSE STANDARDIZATION switch one step at a time and adjust the pH CALIBRATE control until the pen shifts exactly 1 pH unit on the scale or chart. The COARSE STANDARDIZATION switch should provide this 1 pH unit per step shift on any setting of the TEMPERATURE control and regardless of the pH SPAN switch position.

Turn the SPAN switch to one of the MV positions and calibrate the STANDARDIZATION switch to provide 100 millivolts per step. See the instructions for "Millivolt Measurements" on Page 15 and note the switch positions in the examples on Pages 15, 16, and 17. The position of the STANDARDIZATION switch for zero suppression voltage depends on whether +MV or -MV measurements are to be made.

This completes the "Instrument Calibration."

IN CASE OF DIFFICULTY

DIFFICULTY	POSSIBLE SOLUTION
pH/MV Standby Light does not light.	a. Make sure the Power switch on the Recorder is in the Standby mode (for EUW-20A) or is ON (for the EUW-20B). b. Check that the line cord from Recorder is plugged firmly into the power outlet. c. Check that the 11-pin plug on the left side of the EU-20-31 Module is plugged into the Recorder 11-pin socket. d. Check the Recorder fuse.
Measure and/or Record lights are "ON" with Function switch in Standby.	a. Check the Servo Recorder to make sure that only the Power switch is on. It must remain in this mode for pH and MV measurements.
Instrument does not respond to pH change.	a. Check to see if the glass electrode plug is correctly seated in the connector. Check for a cracked or broken glass electrode. b. Check for a plugged reference junction. c. Check to see if the correct buffers are being used.
Pen oscillates.	a. Check the Damping control. Move the control slightly clockwise until the oscillation stops, but do not overdamp.
Sluggish response.	a. See that the electrodes are firmly plugged into the terminals. b. Check for unstable solutions where pH is changing. Use only a buffer solution to check for drift. c. Check to be sure the glass electrode lead does not vibrate during measurements.
Noise and drift.	a. Check to see that the instrument is properly grounded. If a stirring motor or ring stand is used near the electrodes, it is important to connect a grounding wire from each to the same earth ground that the instrument is connected to. b. Check to see that electrode support rod is making electrical contact with the bracket on the adapter chassis. c. Check for bad electrodes. Substitute new ones. d. Check the Null control on the EU-20B Recorder or the Hum ADJ on the EUW-20A Recorder. e. Check for excessive damping in the Recorder.



CIRCUIT BOARD PARTS PICTORIAL

MAINTENANCE

INPUT CIRCUIT

The high impedance input circuit is enclosed to protect it from dirt and corrosion. Do not touch the components with your hands if you perform any maintenance on the input circuit.

ELECTRODE BRACKET

It is quite possible that, during use, chemicals will be spilled on the spring and rubber sleeves on the electrode holder. These parts should be kept clean at all times. If they are damaged, replacement parts are available. See the Replacement Parts List.

SERVO RECORDER

Refer to the Maintenance section of your Heath Servo Recorder Manual.

REPLACEMENT PARTS LIST

The key numbers correspond to the numbers on the Identification Photograph, fold-out from this page, and on the Exploded Drawing, fold-out from Page 23.

Write to the Heath Company for replacement price information for any of the following parts.

U-PLUG ASSEMBLY (#181-601) **

KEY No.	PART No.	DESCRIPTION
1	390-168	Label
2	434-11	Socket
3	440-1	Cap

W-PLUG ASSEMBLY (#181-602) **

KEY No.	PART No.	DESCRIPTION
	390-169	Label
	434-11	Socket
	440-1	Cap

**Write to the Heath Company for the Replacement Price of an assembly in an assembled form.

ELECTRODE HOLDER ASSEMBLY (#181-604)**

KEY No.	PART No.	DESCRIPTION
4	73-4	Rubber grommet
5	204-1010	Rod support bracket
6	250-105	8-32 x 1/8" screw
7	253-71	9/16" flat washer
8	258-67	Spring coil
9	266-80	Support rod
10	455-15	Bushing

CIRCUIT BOARD ASSEMBLY (#181-660)**

KEY No.	PART No.	DESCRIPTION
RESISTORS		
1/2 Watt		
11	1-1	47 Ω (yellow-violet-black)
12	1-48	390 Ω (orange-white-brown)
13	1-9	1000 Ω (brown-black-red)
14	1-11	1500 Ω (brown-green-red)
15	1-90	2000 Ω (red-black-red)
16	1-19	6800 Ω (blue-gray-red)
17	1-21	15 kΩ (brown-green-orange)
18	1-24	33 kΩ (orange-orange-orange)
PRECISION		
19	4-73	330 Ω
20	2-58	1000 Ω
21	2-102	196 kΩ
22	2-276	1.1 MΩ
DIODES-TRANSISTORS		
23	56-45	20 V, 12 mA, zener diode
24	56-71	6.2 V, 7 mA, zener diode
25	57-27	Silicon diode
26	417-100	Transistor 36632
27	417-109	Transistor 2N3566
28	417-118	Transistor 2N3393
29	417-169	Transistor MPF105
CAPACITORS		
30	25-111	1000 μF, 15 volt electrolytic capacitor
31	25-131	250 μF, 25 volt electrolytic capacitor
32	27-62	.68 μF, 600 volt Mylar* capacitor
MISCELLANEOUS		
33	85-333-1	Circuit board
34	215-8	Heat sink

*DuPont Registered Trademark

CHASSIS

KEY No.	PART No.	DESCRIPTION
RESISTORS		
1/2 Watt Composition		
35	1-6	470 Ω (yellow-violet-brown)
36	1-9	1000 Ω (brown-black-red)
37	1-13	2700 Ω (red-violet-red)
38	1-16	4700 Ω (yellow-violet-red)
39	1-23	27 kΩ (red-violet-orange)
40	1-139	100 MΩ (brown-black-violet)
41	1-141	1000 MΩ (brown-black-gray)
Precision		
42	2-22-12	125 Ω, 1/10%
43	2-240	1600 Ω, 1%
44	2-273	20 kΩ, 1/2%
45	2-274	60 kΩ, 1/2%
46	2-85-1	80 kΩ, 1 watt
47	2-200	100 kΩ, 1/2%
48	2-275	1.5 MΩ, 1/2%
CAPACITORS		
Ceramic		
49	21-88	50 pF
50	21-13	500 pF
51	21-27	.005 μF
52	21-16	.01 μF
Mica		
53	20-102	100 pF
Polystyrene		
54	29-2	.01 μF
CONTROLS		
55	11-60	200 Ω
56	11-116	200 Ω 1%
57	10-34	600 Ω
58	11-61	25 kΩ
SWITCHES		
59	60-37	4PDT, rocker
60	60-38	3PDT, rocker
61	60-39	SPDT, rocker
62	63-559	4 pole, 10 position, rotary
63	63-578	1 pole, 15 position, rotary, with control
CHOPPER-TRANSFORMER		
64	68-10	Chopper
65	54-235	Power transformer
METAL PARTS		
66	100-898	Top control panel assembly
67	100-901	Cabinet shell assembly
68	100-1009	Electrode holder assembly
69	200-552	Chassis
70	203-627	Rear panel
72	204-1008	Control mounting bracket
73	204-1009	Switch mounting bracket
74	205-712	Cover plate
75	205-713	Connector mounting plate
76	206-445	Electrometer shield
KNOBS-BUSHINGS		
77	455-50	Knob bushing insert
78	455-71	Knob bushing insert
79	455-86	Knob bushing insert
80	462-264	Knob
81	462-272	Knob
82	462-273	Knob
GROMMETS-INSULATORS		
83	73-4	Rubber grommet
84	75-24	Line cord strain relief
85	75-30	Line cord strain relief
86	75-61	Chassis mounting insulator
87	75-98	Circuit board mounting insulator
88	75-108	Paper insulator
TERMINAL STRIPS-CONNECTORS-SOCKETS-JACKS		
89	431-2	2-lug terminal strip
90	431-5	4-lug terminal strip
91	431-45	6-lug terminal strip
92	432-51	Octal wafer connector
93	432-59	BNC connector
94	432-53	Electrometer input connector with cable
95	434-11	Octal socket
96	434-34	7-pin tube socket
97	434-148	Power socket
98	434-190	Input socket
99	436-22	Banana jack
100	436-25	Pin jack

KEY No.	PART No.	DESCRIPTION
HARDWARE		
#6 Hardware		
101	250-170	#6 x 1/4" sheet metal screw
102	250-8	#6 x 3/8" sheet metal screw
103	250-89	6-32 x 3/8" screw
104	250-56	6-32 x 1/4" screw
105	252-3	6-32 nut
106	254-1	#6 lockwasher
107	254-6	#6 external lockwasher
#8 Hardware		
108	252-4	8-32 nut
109	254-2	#8 lockwasher
Other Hardware		
110	250-351	2-32 x 3/16" screw
111	250-52	4-40 x 1/4" screw
112	250-311	3-48 x 5/8" screw
113	252-1	3-48 nut
114	252-7	3/8-32 nut
115	252-32	Speednut
116	252-103	5/8" nut
117	253-80	1/8" flat washer
118	253-10	3/8" flat washer
119	254-4	3/8" lockwasher
120	255-23	6-32 x 5/16" threaded spacer
121	255-49	5/16" spacer
122	259-10	3/8" solder lug
123	258-1	Coil spring

KEY No.	PART No.	DESCRIPTION
INTERCHANGEABLE SCALES		
	455-12	Blank scale
	455-12-2	6.000 to 8.000
	455-12-3	0.00 to 10.00
	455-12-4	0.00 to 14.00
	455-12-5	0.00 to 5.00
	455-12-6	0.000 to 1.000
MISCELLANEOUS		
124	260-24	Positioning clip
125	266-173	Detent
126	347-1	8-conductor cable
127	412-15	Neon lamp
128	413-11	Neon lamp lens
129	417-169	MPF105 transistor
130	426-2	Binding post
131	437-3	Jack insert
132	453-53	Shaft
133	438-29	Octal plug
134	440-1	Octal plug cap
135	207-62	Latch assembly
	701-11	3-ring binder
		Manual (See front cover for part number.)

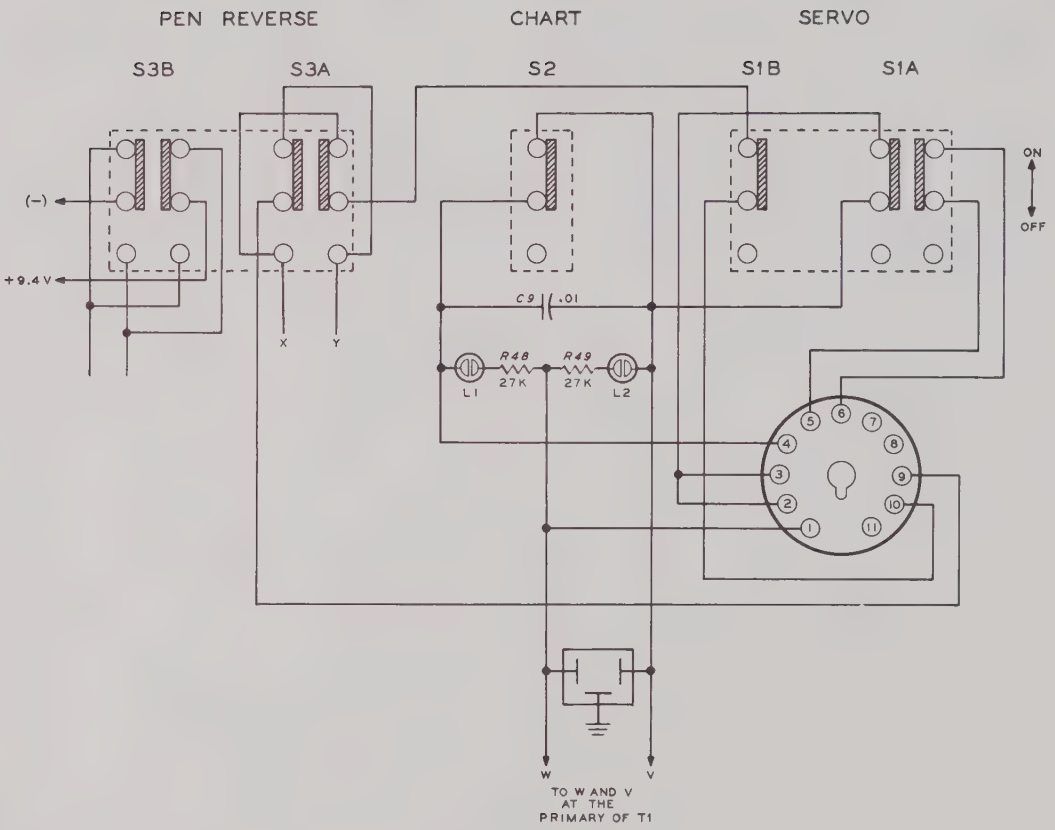
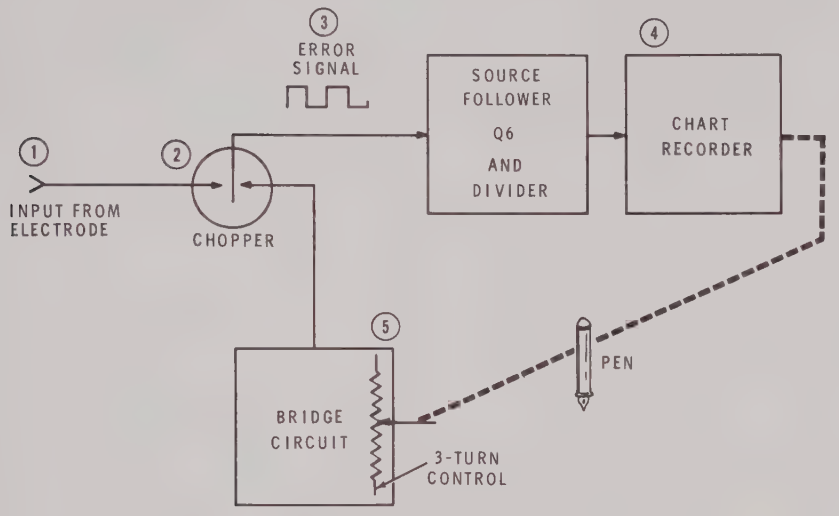

PEN REVERSE
CHART
SERVO
S3B
S3A
S2
S1B
S1A
(-)
+9.4 V
X
Y
C9 .01
R48
27K
R49
27K
L1
L2
ON
OFF
W
V
TO W AND V
AT THE
PRIMARY OF T1

FIGURE 10

CIRCUIT DESCRIPTION



BLOCK DIAGRAM

This pH Recording Electrometer Module replaces the reference (bridge) circuit and the chopper input circuit of the Chart Recorder with its own reference and input circuits. These circuits provide the Recorder with comparison reference voltages that are calibrated in pH units.

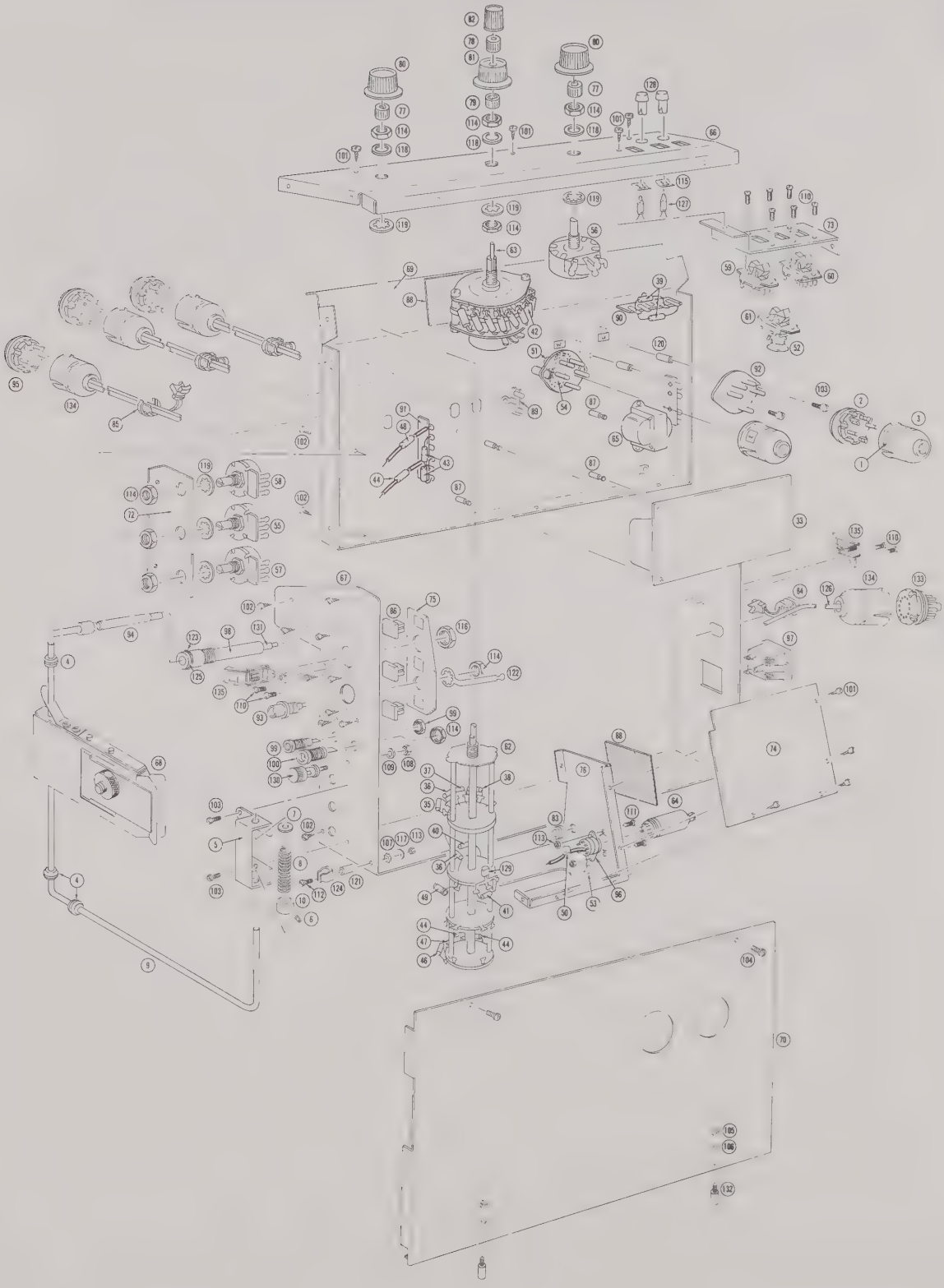
The circuit of this Module is divided into four sections: the chopper-electrometer circuit, the bridge-reference circuit, the switching circuit, and the power supply. Refer to the main Schematic, fold-out from Page 29, and to the partial schematics on the following pages as you read this Description.

RECORDING ELECTROMETER THEORY

The complete pH Recording Electrometer works in the following manner. Refer to the Block Diagram above.

1. The input voltage from the glass and reference electrode pair is coupled to the chopper (pin 6).
2. The chopper compares this voltage to the voltage of the bridge circuit.
3. If the voltages are not the same, the chopper will produce an error signal.
4. The error signal is coupled through Q6 to the amplifier of the Chart Recorder.
5. In the Chart Recorder, the error signal is greatly amplified and causes the servo motor to turn. This moves the pen and the 3-turn precision control in the bridge circuit.
6. As the precision control turns, the reference voltage is automatically varied to reduce the error signal to a negligible value. The motor then stops. At this point, the reference voltage equals the unknown input voltage.
7. When there is no error signal, the servo, pen, and 3-turn control stop moving.

PARTS PICTORIAL
(Exploded View)



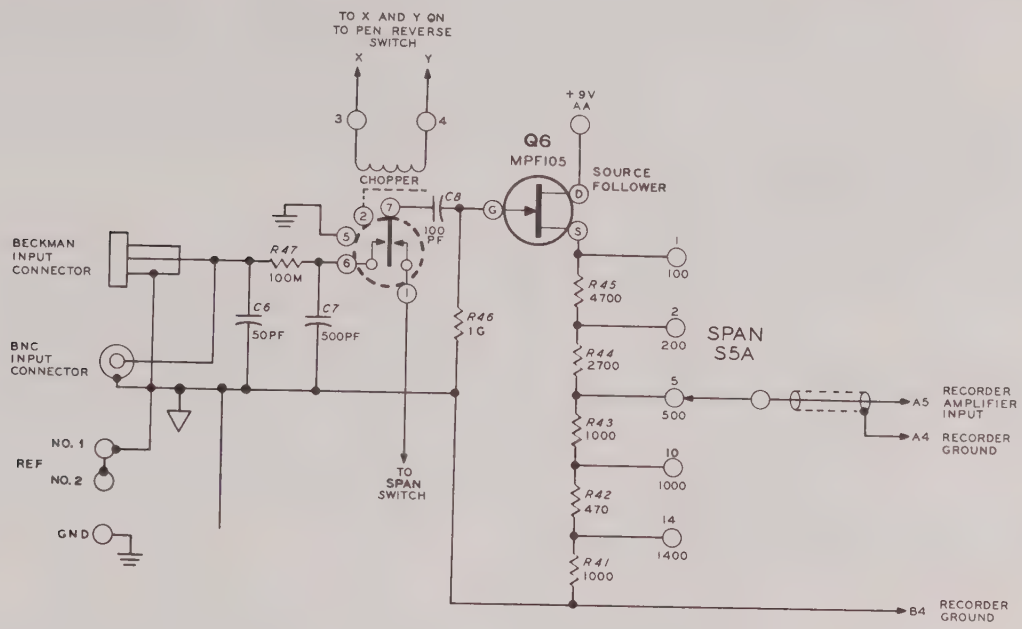


Figure 8

CHOPPER-ELECTROMETER CIRCUIT

The chopper-electrometer circuit (refer to Figure 8) is simple, but especially critical because the high resistance of the electrode system makes it necessary for this circuit to maintain a high input impedance. Therefore, since the input circuit to FET Q6 must remain at a very high resistance above ground, it is shielded to:

1. Reduce the stray noise that is easily picked up by a high impedance circuit.

2. Prevent the high impedance leakage paths that could occur due to someone touching the components (due to the oils and salts present on the human hand).

An input from the electrode is coupled through the input noise filter, R47-C6-C7, to the chopper. The chopper alternately switches between this input and the internal reference voltage from the bridge circuit. If these voltages are not equal, the chopper produces a 60 Hz square-wave error voltage which is applied to the gate of source follower FET Q6.

Signal attenuation for proper damping on the span ranges for pH and MV are provided by the voltage divider in the source circuit of Q6. The output from this section of the Span switch is applied to the input of the Chart Recorder amplifier section, at pin 5 of socket A.

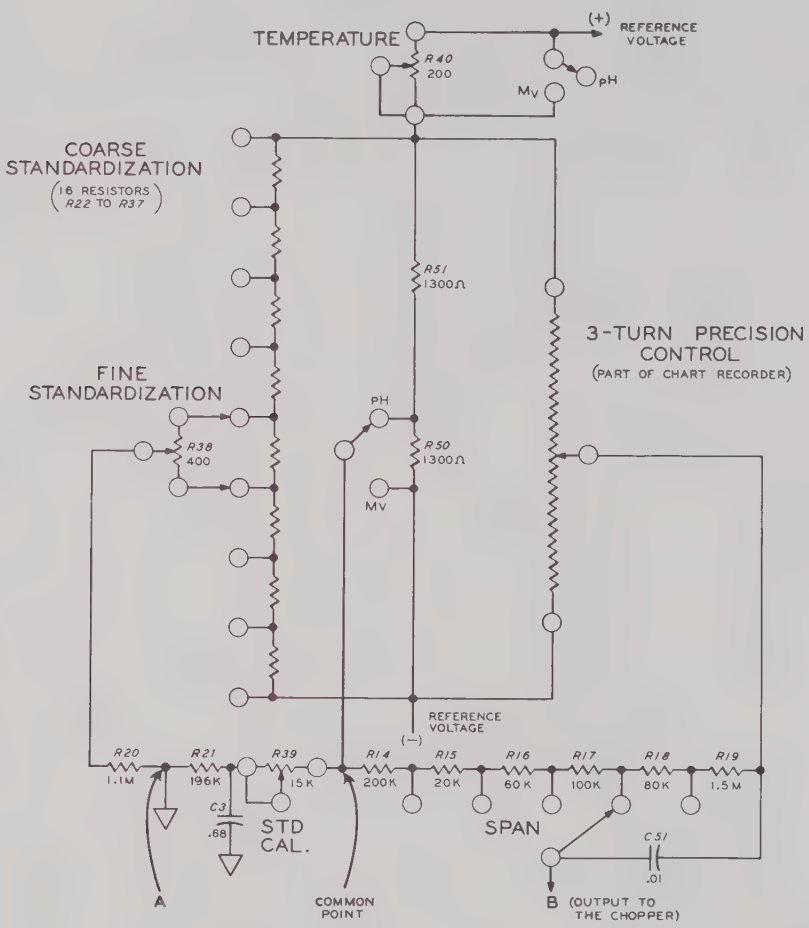


Figure 9 Bridge-Circuit-Simplified Schematic

BRIDGE CIRCUIT

The bridge circuit, which is shown in a simplified form in Figure 9, produces an error-nulling voltage and couples it to pin 1 of the chopper. Although a positive reference voltage (+9.4V) is shown in this Figure at the top of the bridge, with the negative voltage at the bottom, these voltages can be reversed since they are coupled to the bridge through the Pen Reversing switch.

The voltage at the top of Figure 9 is connected through Temperature control R40 to the top of the bridge. This control varies the reference voltage applied to the bridge to compensate for voltage changes in an electrode due to temperature. For example, at 0 degrees C a change of 1 pH produces a voltage change of 54.2 MV across the electrodes, and at 100 degrees C a change of 1 pH produces a 74.0 MV change per pH unit. The Temperature control is bypassed by one of the Span switch wafers for millivolt operation.

The output of the bridge is taken between an arm of the Span switch and circuit ground, point A, which connect into a voltage divider between the arms of the Fine Standardization and three-turn precision controls. This voltage divider includes Span switch resistors R14 to R19, the STD CAL control, and resistors R20 and R21.

Resistors R50 and R51 are connected as a voltage divider between the top and bottom of the bridge. These two resistors, in conjunction with a wafer of the Span switch, connect a common point on the voltage divider to the proper reference point on the bridge. For pH operation, this common point is connected to the electrical center of the bridge zero center operation in the Recorder. For MV operation, this point is connected to the negative DC reference voltage at the bottom of the bridge, allowing the Recorder to operate as a zero center scale reference instrument.

Suppose, for example, that the output of the electrode caused 60 MV to be applied to pin 6 of the chopper. The resulting error signal would be applied through the Recorder to the servo, which would turn the 3-turn control until 60 MV volts were applied from point B on Figure 9 to pin 1 of the chopper. This error-nulling voltage would be produced across the Span switch resistors (R14-R19) by a current flowing between the common point and the arm of the 3-turn control.

When the Standardization switch and control are turned away from the balanced or zero voltage position, a current flows between the common point and the arm of the Fine Standardization control. This causes a voltage drop across the STD CAL control and resistor R21 that apposes, or bucks, the voltage across Span switch resistors R14-R19. In the example given above, the Standardization switch could be adjusted to buck out, or suppress, most of the 60 MV if the area of interest were between 60 and 70 MV. A selected portion of any input can be suppressed in this same manner.

The STD CAL control is adjusted so a voltage equal to 1 pH unit is produced across this control and R21 each time the Standardization switch is moved one step.

FUNCTION SWITCHES (Figure 10 fold-out from Page 24)

The three function switches – Pen Reverse, Chart, and Servo –control the AC voltage inputs to the chopper, chart motor, and servo motor; and they also perform several other switching functions. The AC voltages are connected to this Adapter Module through the 11-pin plug. This plug also supplies the necessary connections to the Servo and Chart switches, which bypass the Servo and Chart switches on the Chart Recorder.

Pen Reverse switch: Switches the phase of the 6.3 VAC supplied to the chopper and, at the same time, switches the polarity of the 9.4 volt reference voltage applied to the bridge.

Chart switch: Turns the chart motor on and off by completing the AC circuit and bypassing the chart switch in the Recorder.

Servo switch:

1. Turns the chopper on by completing the circuit between the 6.3 VAC in the Recorder and the coil of the chopper (through the Pen Reverse switch).

2. Turns the power supply on by completing the circuit between the AC line voltage input (pins 1, 2, and 3 of the 11-pin plug) and the primary winding of the power transformer.

3. Turns on the output amplifier in the Recorder by completing the circuit (through pins 5 and 6 of the 11-pin plug) between its plate and screen circuits and the Recorder's DC power supply.

CHASSIS PLUGS U and W

These two shorting plugs are provided to make the Electrometer more versatile. If plug U is removed, the jumpers between lugs 1 and 2 and between 5 and 6 are disconnected. The input and feedback circuits can then be reconnected for use as a recording photometer, an integrator, or for several other applications. It is also possible to change the given MV and pH spans by introducing a suitable resistor between lugs 1 and 2.

If plug W is removed, the Temperature control is disconnected and the Heath Automatic Temperature Probe can be plugged in in its place, providing accurate, automatic compensation between 15 and 60 degrees C.

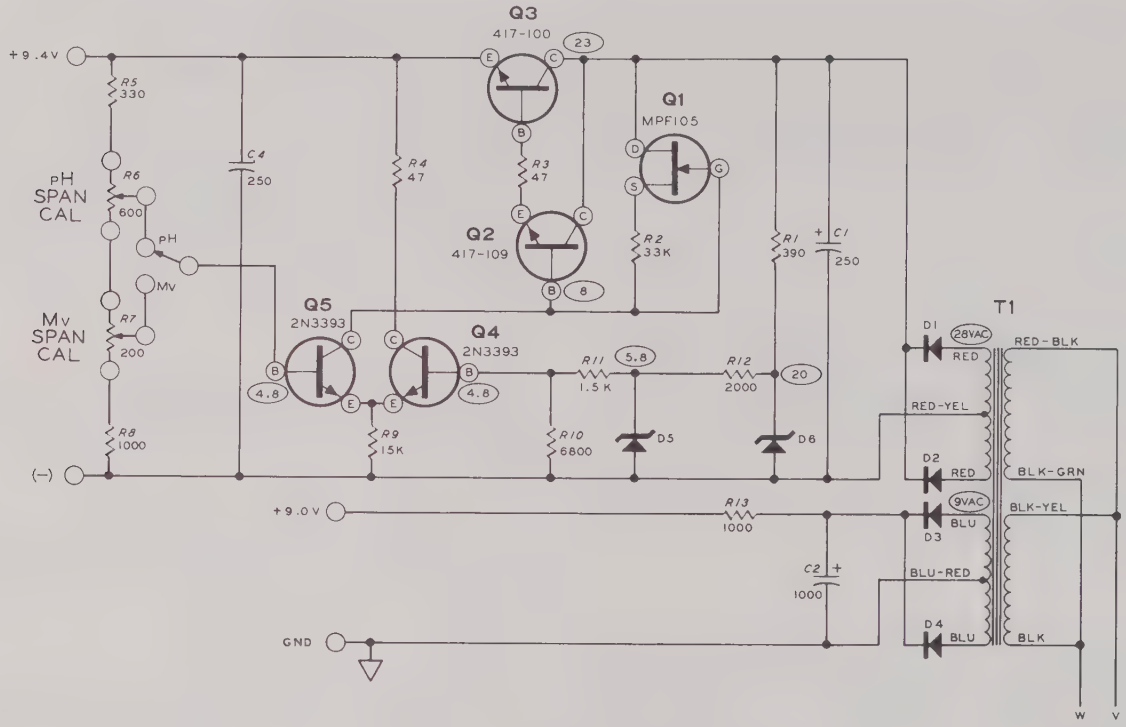


Figure 11

POWER SUPPLY (Figure 11)

The complete power supply circuitry consists of a regulated reference voltage supply and an unregulated 9-volt supply. Each supply is connected to a separate secondary winding of power transformer T1.

AC line voltage is applied from the 11-pin plug and the switches to the dual primary windings of transformer T1. These primary windings can be wired to operate from either a 105-125 or 210-250 volt 50/60 Hz power source. NOTE: Unless otherwise specified, this transformer will be wired for 105-125 VAC operation when the unit is shipped from the factory.

REFERENCE VOLTAGE SUPPLY

Diodes D1 and D2 are connected in a full-wave circuit to rectify the 28 VAC output from the secondary winding of the transformer. The DC output of diodes D1 and D2 is filtered by capacitor C1.

Transistors Q2 and Q3 are connected in a Darlington configuration with Q3 acting as a pass transistor. This results in a gain equal to the beta of Q2 times the beta of Q3. FET Q1 is used as a constant current source to provide drive current for the Darlington pair. Resistor R3 provides decoupling to prevent oscillation.

Resistor R1 and zener diode D6, which has a current of approximately 20 mA flowing through it, act as a preregulator for temperature compensated zener diode D5. D5 which has a current flow of approximately 7 mA, causes a very stable voltage to occur across voltage divider resistors R10 and R11. The regulated voltage that is taken from the junction of R10 and R11 is connected to the base of Q4.

Transistors Q4 and Q5 form a differential amplifier which constantly compares the regulated voltage at the base of Q4 with a sensing voltage at the base of Q5. This sensing voltage is obtained from a voltage divider across the output that includes resistor R5, pH Calibrate control R6, MV Calibrate

control R7, and resistor R8. If the voltage drop across this divider increases, the voltage at the base of Q5 will increase and cause it to conduct more heavily. At this time, more of the drive current from constant current source transistor Q1 will pass through Q5 and common emitter resistor R9 to circuit ground. As the current at the base of transistor Q2 changed, transistor Q2 amplified this change and controls pass transistor Q3. Thus, the collector-emitter current of transistor Q3 is regulated within tolerance and the desired voltage is produced. Conversely, the circuits will operate in a reverse manner if the voltage drop across the resistors should decrease. Capacitor C4 provides additional filtering across the output.

The two Calibrate controls, which are connected to the base of Q5 through a wafer of the Span switch, control the output of the supply. With the Span switch in one of the pH positions, R6 is in the circuit and the output from the supply will be between 6 and 9 volts. In any of the MV positions, R7 is in the circuit and the output will be between 9 and 11 volts.

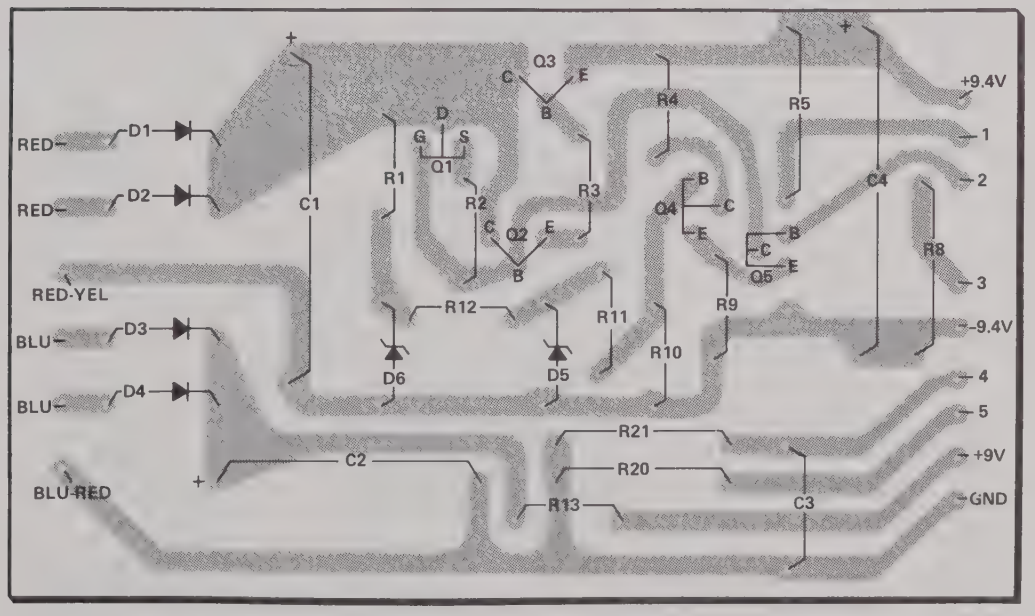
The gain of the differential amplifier is equal to the beta of Q4 times the beta of Q5. Therefore, the amplifier will sense very small changes in voltage and instantly compensate for them.

The gain of the reference voltage supply is equal to the gain of the Darlington pair times the gain of the differential amplifier.

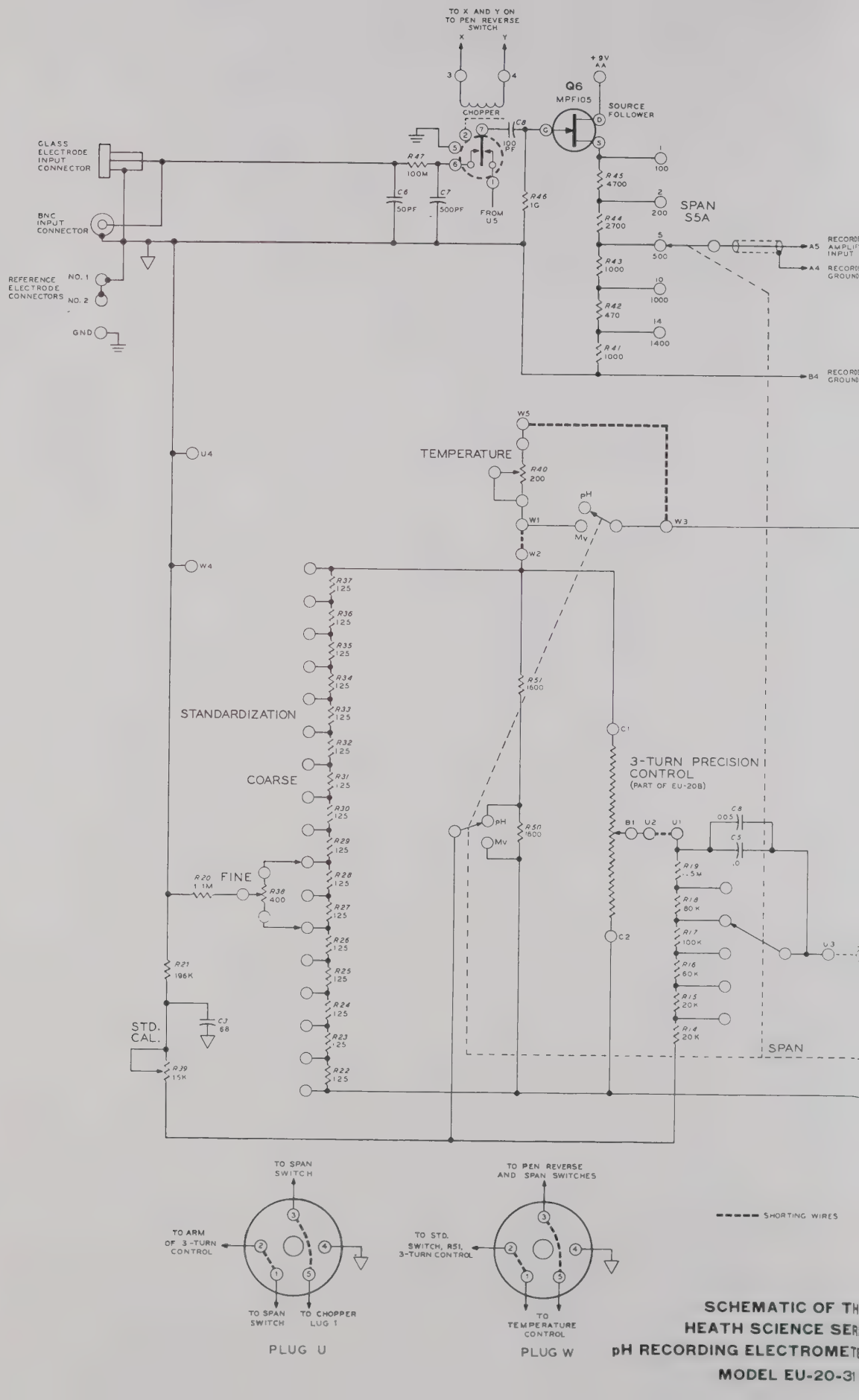
THE UNREGULATED SUPPLY

Diodes D3 and D4 operate in a full-wave circuit and rectify the 9 VAC output from the secondary winding of the transformer. The DC output of these diodes is filtered by capacitor C2. Resistor R13 is a dropping resistor which prevents excessive current should there be a short circuit in the area of transistor Q6.

CIRCUIT BOARD X-RAY VIEW



(VIEWED FROM FOIL SIDE)



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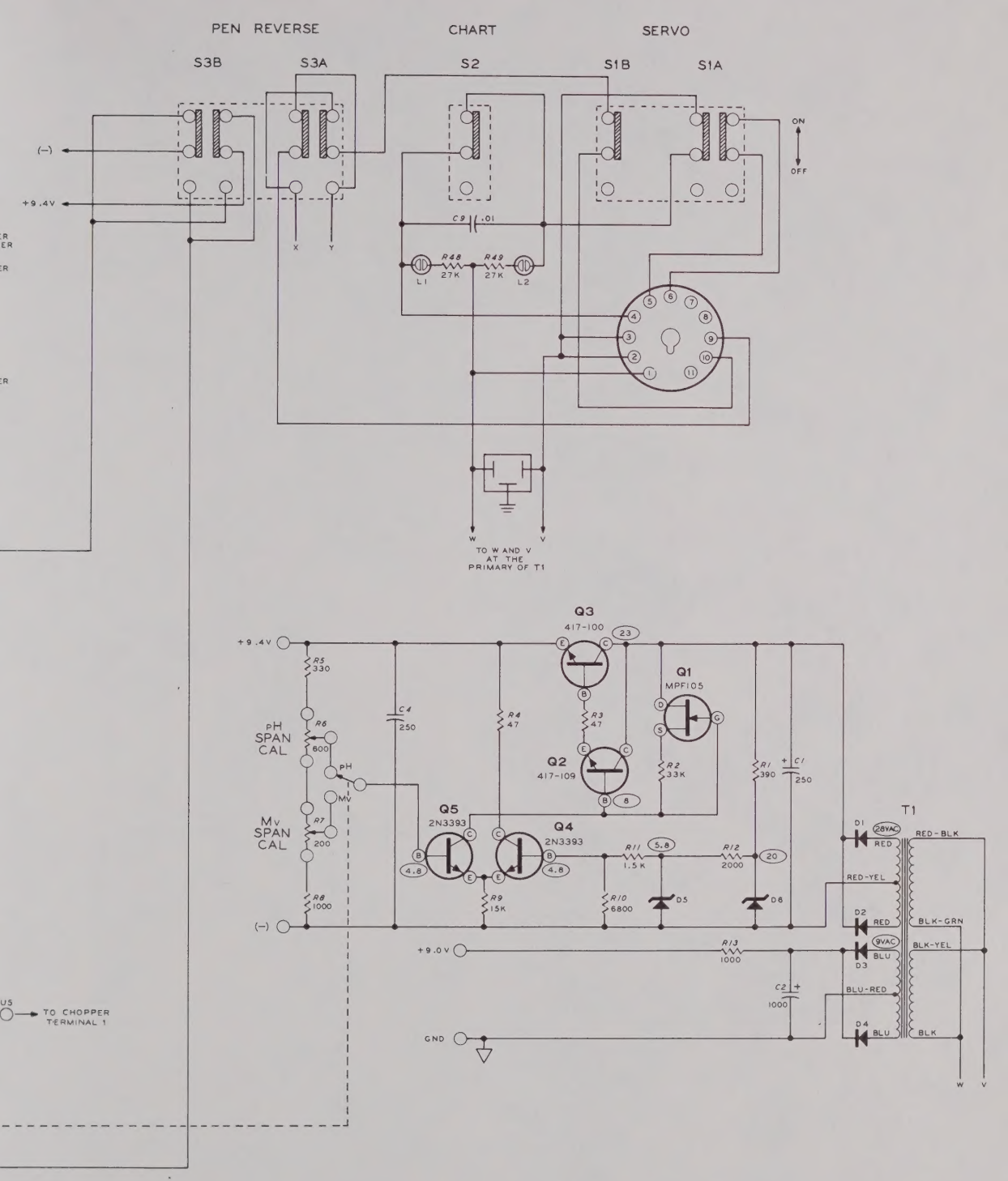

NOTES:

1. ALL RESISTORS ARE 1/2 WATT UNLESS MARKED OTHERWISE.
2. ALL RESISTOR VALUES ARE IN OHMS (K=1000, MEG = 1,000,000).
3. ALL CAPACITOR VALUES ARE IN μFD UNLESS MARKED OTHERWISE.
4. ⬭ INDICATES VOLTAGE READING.
5. ALL VOLTAGES MEASURED WITH NO SIGNAL INPUT.
6. ALL VOLTAGES ARE DC POSITIVE UNLESS MARKED OTHERWISE.
7. ALL VOLTAGES ARE MEASURED FROM POINT INDICATED TO CHASSIS GROUND, EXCEPT AC VOLTAGES.
8. VOLTAGE READINGS TAKEN WITH AN 11 MEGOHM INPUT VOM.
9. VOLTAGES MAY VARY ± 10%.
10. ▽ THIS SYMBOL INDICATES CIRCUIT BOARD GROUND.
11. ⏚ THIS SYMBOL INDICATES CHASSIS GROUND.

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SERVICE INFORMATION

The following Heath Company services are available if you need them: Replacement Parts, Technical Consultation, and Factory Service. Address all correspondence to:

HEATH COMPANY
Benton Harbor, Michigan 49022

For prompt service, use a separate letter for each department you write to.

Replacement parts and repair service are also available at your nearest Authorized Service Center or Heath Electronic Center. These Centers are listed in your Heath Catalog.

REPLACEMENT PARTS

If a replacement part is needed, please include the following information in your letter:

1. Part number and description.
2. Model Number and Series Number of the equipment.

If your equipment is in the Warranty period, add:

3. Date of purchase.
4. Nature of defect.

Heath Company will fill your order promptly. Please DO NOT RETURN PARTS unless they are requested. Parts that are damaged through carelessness or misuse by the customer will not be replaced without cost.

TECHNICAL CONSULTATION

You can write to our Technical Consultants for help with any Heath equipment, or for answers to any questions about the use of this equipment.

The completeness and accuracy of the advice mailed back to you depends entirely on the information in your letter. Be sure to include:

1. The Model Number and Series Number of the equipment (on blue and white identification label).
2. Date of purchase.
3. An exact description of the difficulty. Include switch positions, connections to other units, operating procedures, voltage reading, and any other information you think might be helpful.
4. List everything you have done in attempting to correct the difficulty.

FACTORY SERVICE

If you do not have qualified repair services at your disposal, you can return your equipment to the Heath Company Service Department to have it repaired for a minimum service fee. (Equipment that has been modified will not be accepted for repair.) Refer to Shipping Instructions for details on how to package and ship the equipment.

To be eligible for replacement parts under the terms of the Warranty, equipment returned for factory service must be accompanied by the invoice or the sales slip, or a copy of either. (If you send the original invoice or sales slip, it will be returned to you.)

SHIPPING INSTRUCTIONS

Check the equipment to see that all parts are in place. Then, wrap the equipment in heavy paper. Place the equipment in a strong carton, and put at least three inches of resilient packing material (shredded paper, excelsior, etc.) on all sides between the equipment and the carton.

Seal the carton with gummed paper tape and tie it with a strong cord. Ship it by prepaid Express or insured Parcel Post to:

HEATH COMPANY
Benton Harbor, Michigan 49022

Attach a letter, containing the following information to the outside of the carton:

1. Your name and return address.
2. Date of purchase.
3. A brief description of the difficulty.
4. Your authorization to ship the repaired unit back to you C.O.D. for the service and shipping charges, plus the cost of parts not covered by the Warranty.

WARRANTY

The Heath Company warrants that under conditions of normal use and service it will repair or replace any factory assembled unit whose performance does not meet published specifications and is returned to Heath prepaid within one year following date of shipment. The published specifications are those labelled "specifications" in the catalog and the manual for the unit. The replacement or repaired unit is shipped prepaid by us anywhere in the continental United States or to APO or FPO addresses. Shipments to other places are FOB factory. Heath's obligation is limited to such replacement or repair by Heath, and Heath is not responsible under this warranty or otherwise for any consequential damage or other loss in connection with the unit or its use.

Questions relating to repairs or warranty replacement in the continental United States (APO and FPO included) should be addressed to Heath Company, attention: Customer Relations, or the nearest Heathkit Electronic Center. In all other areas please contact the authorized Heathkit representative in your country, or Heath Company, attention: International Division.

HEATH COMPANY
Benton Harbor, Michigan 49022

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.